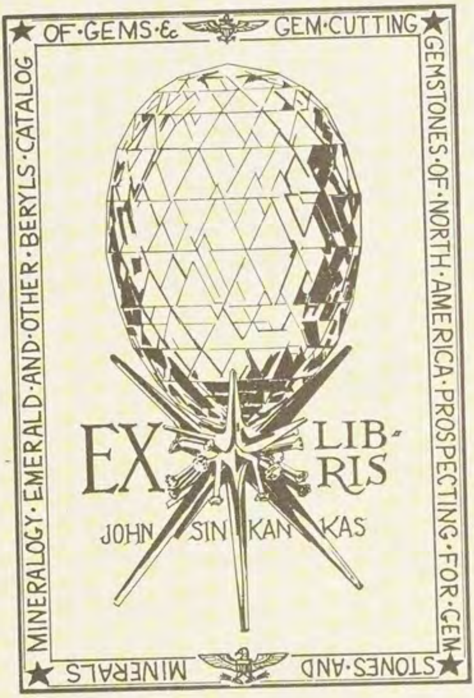
Cat 1^{00} 5/2/83
PLB

Lewis McDonald.

Lewis McDonald,
801 S. Wright St.



GUIDE

TO THE

LIFE-HISTORIES OF ROCKS

BY

C. W. ROLFE
PROFESSOR OF GEOLOGY
UNIVERSITY OF ILLINOIS

TOGETHER WITH A

TABLE FOR THE DETERMINATION OF MINERALS

PREFACE.

The following pages have been prepared with special reference to the needs of our students, and all other considerations have been subordinated to a desire to meet their wants as shown in the work of former years.

In the teaching of all branches of natural history, there is a strong tendency either to make classification so prominent that the student leaves the subject with the idea that ability to recognize a series of forms, and to give to each, without hesitation, some unpronounceable and meaningless name, is about all there is of science; or to take the other extreme, and paying little attention to classification or life-history, to make the subject of morphology so prominent as to give the student an idea that all of science is comprised in the words dissection or analysis.

In the preparation of this little guide, we have endeavored to avoid both extremes, first, by so arranging the matter that the book, taken as a whole, shall reflect the latest and most reliable opinion on the classification of rocks, and at the same time be an efficient key for the determination of species; second, by the selection of material, and use of cross references, to make the subjects of genesis and transformation of rocks so prominent that the student cannot fail to see in these the objective points of his study. Knowledge of names is required, but only because it is thought essential to the proper arrangement of the facts of origin and relationship.

Further, we earnestly hope that before the student has completed the study, he will have come to look upon lithology not as an end, but only as one of the means by which the geologist seeks to unravel nature's secrets.

It is manifestly beyond the scope of a work like this to deal largely with the characters impressed on various species of rocks by decomposition. The study of these characters is intensely interesting, leading as it does to the solution of the most difficult problems in economic geology, but for our present purpose, the student should search until he finds the original or undecomposed rock, which will then fall naturally into one of the species indicated.

It will be observed that sections I to XIII inclusive deal exclusively with the origin and transformations of rocks. The author would suggest that students be drilled on these sections until their subject matter is thoroughly familiar, *before beginning the analysis of rocks*, and that during this analytical work the students be constantly encouraged to look for and explain such evidences of change in composition or structure as the specimens studied show. It seems to him that studies which encourage acquaintance with the relations of rocks and the transformations which they undergo are much more important than mere classification.

Classification should never be regarded as an end in any science, but always as a means to an end, a tool but not a structure.

We regret exceedingly that under present conditions the work must be carried on with hand specimens only. This should never be done, where it can be avoided, for the reason that rock masses are not homogeneous, and it is often possible to select hand specimens representing different species from the same outcrop, a fact which should never be found troublesome in the field.

The student is urged to make for himself a collection from the boulders found in his vicinity. He will be surprised at the number of species and the evidences of decomposition they will furnish.

The key for the determination of minerals is appended for the convenience of the student who may not be familiar with the properties of rock-forming minerals. It is expected that it will be used in connection with Dana's Text-Book of Minerology.

In conclusion, we hope that all who use this book will find its subject as interesting as we have.

C. W. ROLFE.

Urbana, Illinois, July 1, 1904.

CONTENTS.

Paragraphs. *Pages*

TABLE TO AID IN THE DETERMINATION OF CRYSTALLINE ROCKS.

Only essential materials (p. XIII) are named.

References to rocks, which might be mistaken for true crystallines are indicated in italics for comparison.

Quartz, orthoclase (albite) rocks, p. XIV, XXII, *XXIVb, XXV.*
Quartz, oligoclase rocks, p. XVII, XXII, *XXIVb, XXV.*
Quartz, labradorite rocks, p. XVIII, XXII, *XXIVb, XXV.*
Quartz, mica rocks, p. XIV.
Quartz rocks, p. XIV, XXII, *XXIVb XXVIc, XXVII*
Orthoclase (albite), rocks p. XIV.
Orthoclase (albite), hornblende rocks, p. XV, XXII, *XXIVb, XXV.*
Orthoclase (albite), augite rocks, p. XV, XXII, *XXIVb, XXV.*
Orthoclase (albite), mica rocks, p. XV, XXII, *XXIVb, XXV.*
Orthoclase (albite), elaeolite (nepheline) rocks, p. XVI, XXII, *XXIVb XXV.*
Oligoclase, hornblende rocks, p. XVII, XXII, *XXIVb, XXV.*
Oligoclase, augite rocks, p. XVII, XXII, *XXIVb, XXV.*
Oligoclase, biotite rocks, p. XVII, XXII, *XXIVb, XXV.*
Oligoclase, nepheline rocks, p. XIX, XXII, *XXIVb, XXV.*
Oligoclase, leucite rocks. p. XIX, XXII, *XXIVb, XXV*
Labradorite, pyroxene rocks, p. XVIII, XXII, *XXIVb, XXV.*
Labradorite, nepheline rocks, p. XIX, XXII, *XXIVb, XXV.*
Labradorite, leucite rocks, p. XIX, XXII, *XXIVb XXV.*
Anorthite, pyroxene rocks, p. XVIII, XXII, *XXIVb, XXV.*
Anorthite. nepheline rocks, p. XIX, XXII, *XXIVb, XXV.*
Anorthite, leucite rocks, p. XIX, XXII, *XXIVb, XXV.*
Pyroxene, nepheline rocks, p. XX, XXII, *XXIVb, XXV*
Pyroxene, leucite rocks, p. XX, XXII, *XXIVb, XXV.*
Rocks with neither quartz, feldspar, nephelene nor leucite, p. XXI, XXII, *XXIVb, XXVI.*

CLASSIFCATION OF ROCKS.

I. Definition.

The word rock is understood by geologists to include *all masses of inorganic material found in nature, whether solid or loose, homogeneous or composed of a variety of ingredients.* The ingredients of a rock may or may not be of organic origin, but must be minerals. The correctness of this definition is proven by considerations like those which follow. The basis of all soils is finely pulverized rock, and a careful examination of any soil formed in situ, will show an infinite number of gradational forms between the finest dust and the solid rock beneath. A sandstone is merely a bed of sand whose grains have been united by a cement. A clay bank is the decayed form of a rock rich in feldspar. A bed of ore, or mineral of any kind, is the result of the solution, gathering, and precipitation by water of particles widely disseminated through the ingredients of a heterogeneous rock. Some similar relation can be shown for any mineral substance. So as a regular series of forms exists between what is ordinarily called rock and any inorganic material found in nature, and as the progressive changes can, in many cases, be traced by the patient observer, geologists have found it necessary to expand the ordinary meaning of the word, so as to make it cover all these forms.

II. Primary Divisions.

The most satisfactory classification of rocks, all things considered, is that which divides them into two great groups or classes, viz.: *Crystalline Rocks* and *Fragmental Rocks.* This grouping is far from being satisfactory, but is the best which our present knowedge permits.

III. Crystalline Rocks. Origin and Definition.

(*a*) *Origin of Primary Crystallines.* It is the belief of most geologists that at one time the entire earth was a molten mass; that it has reached its present solid condition through gravitation, and the radiation of its heat into space; that during this process, in consequence of the operation of the law "at high temperatures silicic acid displaces all other acids," the outer portion of the sphere came to be composed entirely or nearly so, of silicates; that these silicates when quickly cooled took on the form of amorphous glass, but when cooled more slowly they showed a strong tendency to crystallize, and that the slower the process of cooling, the more complete was the crystallization (p. IX), until completely crystalline forms were produced.

NOTE.—They also believe that the rocks so formed were broken down and their ingredients transported, assorted, deposited, and consolidated into rocks of an entirely different nature (p. IV, V, VI, VII, VIII).

(*b*) *Origin of Metamorphic Crystallines* As these fragmental masses increased in thickness and came under the influence of the earth's contractile forces, they were compressed, fractured, crushed, until sufficient heat was developed to reduce them again to a liquid condition. In this condition they were again converted into silicates under the operation of the law cited above (III, *a*) and losing their heat, were again consolidated into the forms from which they originally came.

(*c*) *Origin of Secondary Crystallines.* Geologists further believe that heated water often heals the gaping wounds produced by earth fractures, by depositing rock material similar to that described above, or in the case of closed fractures it transforms (p. VI) their walls into similar materials. (Examples of this last action are to be seen on a small scale in the ridges projecting from the surface of some boulders).

These considerations give us the foundation for our first great group, called *Crystalline Rocks.*

NOTE.—The name chosen for this group is peculiarly unfortunate in that it seems to put the idea of crystallization forward as the crucial test of membership, while the fact is that many of its members posses no crystalline structure whatever, and others are only partially crystalized; and that many rocks whose components are completely crystallized belong to the other group. Silicated rocks would have been a better name, but this again would lead us into error, for while all members of this group are composed of silicates so far as their main constituents are concerned, it is by no means true that all rocks which are mainly composed of silicates are classed here.

Definition.—The class of crystalline rocks, then, must be held to include *all groups of silicates, whether possessing a crystalline structure or not, formed in either of the three ways* (III, *a*, *b*, *c*) *indicated above, whose ingredients have not been broken or transported since they took on their present composition*

IV. Fragmental Rocks. Origin and Definition.

(*a*) *Origin of mechanical fragmentals.* All rocks are porous. Experiments show that dry rocks will absorb from 3 to 40 per cent. of their bulk of water. A fair average for all rocks would perhaps be 13 per cent., or about one gallon to each cubic foot.

Geologists believe that as soon as the surface of the earth had become sufficiently cool to admit the presence of water, rain fell, bringing with it acid gases dissolved from the atmosphere. These dilute acids not only filled the joints and crevices of the rocks, but penetrated their pores and permeated their entire mass. Once within the rock, acting under the law "at ordinary temperatures silicic acid may be displaced by other acids," these acids attacked the crystalline silicates, causing a series of changes (VI *a b*) whose ultimate effect was to break them down, dissolving and carrying away some portions, while the remainder was left in a more or less disintegrated condition. Such processes are believed to have broken down the primitive crystallines. We know they are disintegrating the crystallines of today, forming heavy deposits of residual material such as china clay, soap stone, serpentine, magnetic iron ore, etc., etc., and examples of every gradation between these forms and the unchanged crystallines are found in abundance. In situations where the conditions are favorable, these disintegrated materials are picked up by surface water, and, together with other particles loosened by frost or corrosion, are borne away, finding temporary lodgment perhaps at many intermediate points, but ultimately reaching the sea. The transporting water depends on velocity of motion for its carrying power. A slight decrease in velocity may cause it to deposit a large part of its load, while a small acceleration may increase its burden many fold. In consequence of this the transported material will be assorted and deposited as beds of gravel, sand, and clay, and these will in time be cemented by the precipitation of lime, iron, silicia, etc., and become conglomerates, sandstones, and shales (XXIV).

(*b*) *Origin of Chemical Fragmentals*. The materials taken into solution during the disintegration of crystalline (or other) rocks are carried by the underground currents until they reach the surface through springs, and thence by streams to the ocean. During this journey it is not unusual for one or more of these materials to meet conditions which cause its precipitation, and as the precipitating agencies are stationary, while the water is always in motion, large deposits of materials which formed but a small portion (often too small for detection by ordinary means) of the decomposed rocks are found. Sometimes this precipitation occurs in a neighboring rock, entirely changing its character (Clinton iron ores), sometimes in fissures through which the currents are passing, or in the rocks which form their wall (most deposits of the useful metals), again it happens just as the water reaches the surface (the calcareous and silicious sinters of hot springs, and some deposits of metals), sometimes it occurs on the way to the sea (bog iron ore) but mostly after it has reached the sea (limestone, diatomaceous earth, rock salt, etc.) (XXVI)

(*c*) *Origin of Volcanic Fragmentals.* If during a volcanic eruption large quantities of superheated steam escape, the violent explosions of the steam bubbles will throw small particles of lava high into the air. These particles falling build large deposits of fragmental material known as ashes, lapilli, tufa, etc., which may afterward be cemented into more or less compact rocks. (XXV).

(*d*) *Origin of Homogeneous Crystallines.* The processes described under physical and mechanical metamorphism (p. VII-VIII) frequently transform the rocks described above (IV a, b, c) into forms which are completely crystalized. These rocks, although completely crystalized, are readily distinguished from those of the crystalline series by their chemical composition or their evident derivation from fragmental material without serious chemical change. Examples are marbles, clay slates, quartzites, etc. (XXVII).

(*e*) *Origin of Carbonaceous Sedimentaries.* Geologists also place here all rocks derived from partly decomposed animal or vegetable matter, and all deposits of carbonaceous material however formed. Examples, coal, graphite, asphalt, etc. (XXVIII).

Definition. Fragmental rocks may be defined then as including:

All rocks made up of fragments of other rocks, and all residual matter left by their decomposition. (IV a, also VII a, b, and XXIV).

All materials precipitated from solution except those indicated in p. III c. (IV b, also VI c, d, and XXVI).

All fragmental volcanic debris. (IV c, also XXV).

All crystalline masses, not silicates, and all crystalline silicates evidently derived from crystallization of fragmental material, without serious chemical change. (IV d, also VII, VIII and XXVIII).

All carbonaceous rocks. (IV e, also XXVIII).

V. Metamorphism.

Before entering upon the subdivision of these primary groups, it will be convenient to briefly consider the subject of metamorphism, as it will throw much light on their mutual relation.

Definition Metamorphism literally means change of form, and would, if so taken, include all transformations to which rocks are subject, even those resulting from the operation of such mechanical forces as are indicated in paragraphs IV *a* and *c*, XXIV and XXV, by which crystalline rocks are converted into fragmentals, but its meaning will here be so restricted as to include only those changes indicated in the following paragraphs. For convenience of description these metamorphic changes will be considered under three groups, viz: *chemical metamorphism*, *physical metamorphism*, *and mechanical metamorphism.*

VI. Chemical Metamorphism.

Definition. All changes which affect the chemical composition of the mineral ingredients of a rock, or of the rock itself, are included here.

(*a*) *Mineral transformation in Crystallines.* It is a well known fact that earth water in its passage through the rocks brings various substances into contact under conditions which induce chemical interchanges, certain bases or acids being freed from their combinations, while others take their places. Such changes transform one mineral species into another, and since, as will be shown later (p. XIII), it is the character of the contained minerals that give to a rock not only its name, but its particular properties as well, such changes will result in the gradual passage of a rock from one species to another. Examples are the change of orthoclase into oligoclase, by which a granite (p. XIV) or a syenite (p, XV) becomes a diorite (p. XVII); or the change of orthoclase into mica, by which a granite (p. XIV) becomes a greisen. (p. XIV).

(*b*) *Origin of Residual Matter.* Under other conditions earth water will change the complex compounds which form the minerals into simpler forms by abstracting the more soluble bases without exchange. Examples are the conversion of peridotite (p. XXI) into serpentine by the removal of lime, or iron, or both from its olivine and augite; or the formation of china clay from granite, through the abstraction of potash or soda from its feldspar.

(*c*) *Origin of Secondary Minerals.* The ingredients, freed from their combination in one mineral, often combine with other substances carried by earth water and form new mineral substances, called secondary minerals, typically foreign to the rock. If such additions form but a small percentage of the rock mass, they are regarded as accidental minerals (p. XIII), but if more abundant, they may change the character of the rock entirely. Examples are the introduction of tourmaline into granite, making tourmaline or schorl granite (p. XIV), or of garnet making garnetiferous granite (p. XIV) or of the mineral chiastolite into mica schist, making chiastolite schist (p. XXII) or the addition of quartz to syenite (p. XV), thus transforming it into a granite (p. XIV).

(*d*) *Mineral Transformations in Fragmental Rocks* Changes similar to those indicated under (*a*) frequently occur in fragmental rocks, completely transforming them. Examples are the derivation of dolomite (p. XXVI*d*) from ordinary limestone (p.XXVI *d*) through the replacement of lime by magnesia, or the conversion of beds of dolomite (p. XXVI *d*) into iron or lead ore by the replacement of magnesia by iron or lead.

(*e*) *Origin of Secondary or Metamorphic Crystallines* Through the agency of heat and pressure, fragmental rocks are continually being transformed into crystallines, as described under p. III *b*.

NOTE.—From what has preceded, we see that rocks are not the stable substances that we have been accustomed to conceive them. The processes of chemical metamorphism are going on everywhere and at all times, transforming one species of crystalline rock into another, converting beds of limestone or dolomite into rich deposits of ore, filling cavities in the rocks with beautiful crystals of adventitious minerals, and when the processes of erosion, transportation and deposition have accumulated great thicknesses of fragmental rocks, which under the influence of secular contraction have begun to crumple and fold, these same agencies change them all back into crystalline rocks like those from which they were derived.

VII. Physical Metamorphism.

Definition. Under this heading are included *all those changes which affect the physical characters or molecular groupings of minerals or rocks, without materially altering their chemical composition.*

The term then covers a very large number of changes which rocks undergo, some of which are of minor importance and will not be considered here. We shall call attention only to the three directions in which this kind of metamorphism is most frequently manifested.

(*a*) *Devitrification and Crystallization Induced after Solidification in Crystallines.* When a volcanic rock which has cooled so quickly that the molecules did not have time to arrange themselves in crystalline forms (p. IX) and which, in consequence, has a glassy structure, is exposed under proper conditions to the action of earth water for a sufficient length of time, a molecular rearrangement will take place. This rearrangement will usually first manifest itself, microscopically, in the change called devitrification, a process which consists in the gathering of like molecules into little granules and needles, with the result that the rock loses its glassy appearance and takes on a stony (*felsitic*) look. In some cases this change is preceded by one called *spherulitization*, by which devitrification begins at certain points long before it affects other parts of the mass, and results in the formation of spherical masses of radiating needles scattered through a glassy matrix. The same processes which bring about devitrification, if carried further, will cause the development of a *porphyritic* (p. IX) structure, and if carried still further the mass will finally become *holocrystalline* (completely crystalline). In this process, other things being equal, the higher the temperature of the water the more rapid will be the change.

An excellent example of the effect of these processes on a typical obsidian (p. XIV) is seen in Obsidian Cliff in the northwestern part of Yellowstone Park. Here we find illustrations of every step in the transformation of a glassy lava into first a porphyritic, and then a holocrystalline or granitoid rock.

(*b*) *Crystallization Induced in Fragmentals by Earth water at Ordinary Temperatures.* As commonly used the word devitrification applies to these processes as developed in volcanic rocks alone, and refers to the crystallization of their ingredients; but amorphous granular rocks may, by a very similar series of changes, develop a crystalline structure. Rocks so produced, while not uncommon, are relatively rare, and their texture is usually so coarse that they have little value.

(*c*) *Crystallization Induced in Fragmental Rocks by Heat and Pressure.* Clastic rocks, under the long continued influence of a temperature slightly below the fusing point, often become completely crystallized without any marked change in chemical composition. Such changes are only found in mountain ranges or regions where the violent earth movements necessary to develop the required heat have taken place. Examples are the transformation of limestones (p. XXVId) and dolomites (p. XXVId) into marble (p. XXVII), of sandstones (p. XXIVb) into quartzites (p. XIV), or of bituminous coal into anthracite.

VIII. Mechanical Metamorphism.

Definition. This includes *such changes of structure as result directly from the action of mechanical forces on the rock mass in situ, but does not include those effected by corrasion or transportation.*

Mechanical differs from chemical metamorphism in that it involves no change in the chemical constitution of the rocks affected, and from physical metamorphism in that it does not include changes in crystalline structure. Physical metamorphism deals with the grouping of the physical molecules which make up the mass without changing the chemical molecules. Mechanical metamorphism deals with those changes which may come to the rock mass itself, without affecting its molecular groupings, physical or chemical. The forces producing these different metamorphisms frequently act together, hence if the distinction is not kept clearly in mind, the student will be apt to lose sight of certain of the agencies which have operated to bring the rock into

into its present condition, and be led to wrong conclusions. The most prominent classes of rocks which arise through the action of mechanical metamorphism, acting alone or in combination with the other forms, will be described in the following paragraphs:

(*a*) *Origin of Granitoid Gneiss.* If a fine grained substance, like a mass of clay, be subjected to severe pressure, the constituent grains will be flattened in a direction approximately transverse to the line of pressure, causing the mass to take on a fibrous appearance in transverse section, and to cleave more easily in that direction than in any other. Microscopic examination of the ordinary clay slate shows that its grains are so arranged, and some authors have assigned this as the sole cause of slaty cleavage. This conclusion is hardly warranted, as it fails to explain the regularity and definiteness of the cleavage. The explanation now accepted will be given below.

If such severe pressure be applied to a strongly heated crystalline mass, the crystals will tend to arrange themselves with their long axes at right angles to the line of pressure. This would give to the rock a fibrous appearance without distinct banding. Such a rock would be called a *Granitoid Gneiss* and would represent the first step in the transformation of a crystalline granular rock into a schist.

(*b*) *Origin of Gneiss.* If the strains in the case just mentioned were of such a character as to develop a series of incipient fractures, water in its passage through the rocks would find less resistance along those planes than in other directions, and would form here new minerals (p. VI, a, b, c, d), mostly micas, which would give to the rock a more distinctly banded appearance. This rock would have essentially the same composition, and would still fall naturally into the same mineralogical group (p. XIII) as its original, if it were not for its distinct banding. Such a rock is called a *True Gneiss.*

(*e*) *Origin of Slates Phyllites.* If the strains caused a series of actual fractures running parallel to each other at small intervals without accompanying chemical change, the resulting rock would be a *Slate* but if chemical metamorphism produced slight mineral changes along the planes of cleavage, the rock would be called a *Phyllite.* The essential difference between a slate and a phyllite lies in a sheen or thin layer of adventitious minerals deposited on the surfaces of the plates of the latter.

(*d*) *Origin of Schists* If the strains cause actual fractures, whether parallel or not, and chemical metamorphism following induces *large* changes in the mineralogical character of the rock, it becomes a *schist*. The principal difference between a slate and a schist lies in the large amount of mineralogical change which has taken place subsequent to the fracturing. A less important difference lies in the fact that the fractures producing cleavage in slates are always nearly or quite parallel, while those producing schists may or may not be so.

NOTE.—It should be noted that the facts stated in a, b, c and d above, together with those found in p. XXXVI, X, XI, XXII, show that the groups of rocks known as gneisses, slates, phyllites and schists may arise from the metamorphism of either crystalline or fragmental rocks.

It should also be noted that cleavage produced by fracture, as indicated above, must be carefully distinguished from that produced by an alternation of coarse and fine sediments, or sediments of different kinds, in bedding. This constitutes the main difference between some slates and shales (p. XXIV c, Shales).

IX. Classification of Crystalline Rocks. Subdivision on Genetic Grounds.

There is a growing belief among geologists of the present generation, that most, perhaps all, of the crystalline rocks now exposed on the surface, or lying within the reach of man, are products of metamorphism; that is, they came into their present condition through the operation of the same forces which produce volcanoes. Hence the primary subdivision of crystalline rocks is based upon the considerations indicated below.

Crystallization and Origin of Porphyritic Structure. All mineral substances tend to assume a crystalline form when they solidify. The attraction which draws molecules of like kinds together is, for want of a better name, called *crystalline force*. This force, if free to act on a complex mass of fused minerals, slowly brings the molecules of each kind into groups by themselves. and causes each of these groups to take on the outlines of some geometric form, but in order that this process shall be perfectly carried out, the mass must remain for a long time in such a condition that its molecules will be free to move. If the fused mass be suddenly cooled, giving its molecules no opportunity to group themselves in accordance with their affinities, it will assume the form of a structureless glass (obsidian) If cooled a little less quickly, this grouping will begin before the resistance of the stiffening mass prevents, and the glass, if examined in thin section under the microscope, will be found to contain large numbers of hair-like, rod-like, or moniliform bodies, which are in reality incipient crystals. These bodies (trichites, microlites, etc.), will increase in number as the time of cooling is lengthened, and when they become abundant will show a marked tendency to gather in clusters, and to acquire crystal outlines. In this condition the mass will consist of definite, well-formed crystals, imbedded in a more or less glassy magma. Such rocks are said to have a *porphyritic* structure, and the name is also extended to include forms whose matrix is so filled with microlites, etc., as to have lost its glassy appearance and taken on a stony (felsitic) look, or even become micro-crystalline (XI a). As the cooling process is still farther retarded, the proportion of crystals will increase, and that of magma decrease, until holocrystalline (completely crystalline) forms are produced.

Subdivision. Physical conditions, then, which control the rate of cooling, will also determine the structure of a rock. It will be seen at once that such a consideration brings into close relation all rocks which have passed through the same genetic stages, and hence is of primary importance in classification. It is upon this basis that the division of all crystalline rocks into *intrusive* and *effusive* forms is made.

See note following paragraph XI.

X. Intrusives.

One of the results which attend the foldings and crushings incident to mountain making (p. IIIb), is the formation of pockets of molten rock, which may be very large. In case the convulsion which formed these pockets, or a subsequent one, did not open a passage for the liquid rock to the surface, or in case such an opening was made, but only part of the liquid mass was ejected, the whole mass, or that portion which remained deeply buried in the earth, would cool and solidify very slowly, so slowly that all its ingredients would have ample time to arrange their molecules in crystal forms (p. IX). Since the cavity which holds such a liquid mass is circumscribed, and the mass, owing to its depth beneath the surface, is under great pressure, those ingredients which first separated from the liquid magma will be free to take on perfect crystal outlines, but after these perfect crystals have become so numerous as to form a network through the entire mass, the remaining material will be compelled to crystallize in the interspaces, and hence while the crystalline structure is perfect, crystal outlines are usually wanting in the materials which solidify last. In masses which solidify under less pressure, all the components may have crystal outliness.

Definition. All crystalline (p. III) *rocks, then, which have a holocrystalline structure, whether all ingredients have perfect crystal outlines or not, are classed as Intrusives, unless barred out on geological considerations.* (See notes at close of paragraph XI).

XI. Effusives.

If the convulsion which produced the pocket of molten rock, spoken of in paragraph X, or some subsequent movement, caused an opening leading to the surface, the lava would rise in the fissure and overflow. Whenever the sheet of extruded lava was thin, or was placed under conditions which caused to it cool quickly, few, if any, crystals would form (p. IX), and the mass would solidify as a natural glass, but when the sheet was thicker, or other conditions caused it to cool more slowly, crystals would form, whose number would be proportioned to the rate of cooling. It is for this reason that most effusives have a *porphyritic* (p. IX) structure, a small proportion are *glassy*, and a still smaller proportion *holocrystalline*. These last cannot be distinguished from intrusives except on geological grounds.

(*a*) *Origin of Crystals of Two or More Generations.* The pockets of molten rock buried deep in the earth, from which these floods come, are not usually formed by the same convulsion that opens a channel for their extrusion, but lie for a long interval at the place where they were formed. During this interval, portions of the more readily crystallizable substances separate and appear as perfectly formed crystals, which are erupted with the lava. During the process of solidification other crystals of the substance are formed, and these two sets of crystals, formed under widely different circumstances, will always present different facies. Such crystals are said to occur in *two generations*, and the rocks in which they are found are called *prophyritic*, whether the ground mass is glassy, or felsitic, or completely crystalline.

(*b*) *Origin of Amygdaloidal Structure.* The surfaces of a lava sheet sometimes cool so quickly that the stiffening mass imprisons quantities of steam bubbles, which, on condensation, leave vesicles in the rock, hence the term *vescicular lava.* When subsequently earth water has deposited quartz, calcite, copper or other substances in these vesicles so that the whole mass seems to be made up of rounded (almond like) particles inclosed in cells, the rock is called an *amygdaloid.*

Definition All crystalline rocks having a glassy or porphyritic structure (unless they are excluded for geological reasons) are classed as effusives.

NOTE.—From what has been said it will be evident that while in the main all crystalline rocks will readily fall into one of the two groups indicated, there is after all no sharp line of distinction between them. (*a*) Every effusive mass must be connected by a lava-filled conduit with the pocket from which it was derived, and some portion of the original mass must remain in the pocket; hence the effusive forms must pass insensibly through the rock in the conduit into intrusives. (*b*) Again when lava is poured out until the mass has attained a thickness of thousands of feet, the lower portions of this mass will cool under conditions closely analogous to those under which intrusives are formed, and hence the same structures will be generated. (*c*) It is frequently the case that lava rises from the pocket in which it was formed through a conduit which extends only part way to the surface, and spreads out in horizontal sheets between the bedded rocks. If such a sheet be thin, and be injected between cold rocks, the conditions under which solidification would take place would be quite similar to those under which effusives solidify, and so would produce similar structures. We see then that effusives grade insensibly into intrusives, that under certain conditions effusives may take on the facies of intrusives, and that at times intrusives come to look like effusives. Under such circumstances careful geological field study is the only means we have of putting rocks into their proper places.

NOTE.—Many authors, following "Rosenbusch," recognize a third group, viz: *Vein Rocks*, including forms which have solidified in the volcanic necks (dikes or other forms) connecting intrusive with effusive masses, and also those forms which have been deposited by secretion from the walls of fissures (p. III c), but the researches of the last few years have brought to light so many instances of structures identical with those attributed to vein rocks, which have certainly been formed in an other way (p. III c,) that further retention of the group seems impossible. Iddings held several years ago that Vein Rocks was a group "whose rate of disappearance is proportional to our advance of knowledge."

XII. Subdivision on the Basis of Age.

Mountains have been builded, rocks have been folded, fractured, crushed, and melted, and volcanoes have erupted in all periods of the earth's history since it became a solid mass; hence, intrusives and effusives have been formed in every period, and are now forming. Some years ago an attempt was made by some prominent lithologists to relegate all intrusives to pretertiary times, and to divide the effusives into *Paleovolcanics* or those which were erupted before the beginning of the Tertiary, and *Neovolcanics* or those which have been thrown out since that time. The first proposition we now know to be untrue, for great masses of intrusives have been proved to date from tertiary time, having since been uncovered by erosion, and the second can only be maintained on geological grounds, for while it would at first sight seem that devitrification (p. VII a) and other forms of metamorphism induced by weathering would have gone much further in pretertiary than in more recent forms, the variation in conditions, favorable or unfavorable to weathering, to which rocks are subjected, will more than offset this, hence we shall assume that geology alone can assign a given mass to the paleovolcanic or neovolcanic series.

XIII. Subdivision on the Basis of Minerological Composition. Mineral Groups.

The differentiation of a cooling mass into its constituent minerals has been outlined in paragraph IX. As the cooling magmas differ from each other in chemical composition, they will upon solidification differ also in mineral constituents. Hence upon this basis each of the preceding divisions has been subdivided into groups or series. As each of these mineral groups has representatives in both intrusive and effusive rocks, it has been thought best in the key at the beginning of these notes and in the classifications which follow, to subordinate the division into intrusive and effusive forms, to that into mineral groups.

Definition. A *mineral group*, or more briefly, a *group* of crystalline rocks includes *all those which have the same mineral content, as shown by the predominant ingredients in holo-crystalline forms, or by the predominant porphyritic crystals in the more glassy kinds.*

NOTE.—Just here a word of caution. It has been proved by Iddings and Hague that representatives of each of the following mineral groups may be obtained from the same magma by varying the conditions under which it is cooled, hence, it happens that different parts of a large rock mass may afford specimens having widely different mineralogical compositions. For this reason the character of a given mass should never be determined from a single specimen, or in fact from hand specimens at all, but each should first be studied in the field, and representative fragments taken for more detailed study.

In describing the mineral groups the mineral contents of each will be divided into *Essential Minerals*, *Accessory Minerals and Accidental Minerals.*

By *essential minerals* is meant those which *must* be present in sufficient quantity to be recognized at once as principal ingredients of the rock. That is, each must form a considerable percentage of the whole mass.

By *accessory minerals* is meant those whose quantity makes them less prominent as ingredients, but which are usually present in small amounts at least.

By *accidental minerals* is meant those which are only occasionally met with, but which may be found in such quantity as to give to the rock a varietal name, as garnetiferous granite, andalusite schist, etc. They usually result from chemical metamorphism of the original rock.

XIV. Granite Group.

Essential—Quartz, orthoclase or albite.

Accessory—Mica, amphibole, pyroxine.

Accidental—Iron oxides, zircon, apatite, plagioclase, topaz, talc, garnet, tourmaline, etc.

Subgroup, Granitic Intrusives (p. X).

All rocks belonging to this class are completely crystaline. The quartz is in irregular grains, and hence was probably the last ingredient to solidify (p. X).

The feldspar is typically orthoclase, but is often albite, and some part may have been transformed into oligoclase, or even labradorite. The crystals are usually more perfect in form than those of quartz.

Some form of mica is usually present. Biotite is the most common, then muscovite, then lepidolite. The various stages in the transformation of feldspar into mica may frequently be traced (p. XI).

Granite weathers chiefly by the decay of its feldspars.

Granite.—A relatively rare granitic rock in which more or less muscovite is present. Biotite may be present also.

Aplite.—A granite composed almost solely of quartz and orthoclase or albite, very little muscovite or other accessory being present. It is usually found in veins.

Graphic Granite or Pegmatite.—An aplite in which the grains of quartz have curious angular forms resembling hieroglyphics.

Greisen.—A granite in which, through metamorphic action, most or all of the feldspar has been transformed into muscovite or some light mica. It is commonly associated with tin ore.

Granitite.—The most common form of a granitic rock. The mica is always biotite or some dark colored variety.

Granite Porphyry.—A granitite which contains large well developed crystals of feldspar, in a ground mass of ordinary granite.

Granulite.—A granite or granitite in which metamorphic action has produced a considerable percentage of garnet

Amphibole Granite.—A granite in which hornblende takes the place of much (all) of the mica.

Augite Granite.—Like the above except that augite takes the place of amphibole.

Mica Granite.—A granite in which mica is the predominating dark material.

Tourmaline Granite.—A granite or granitite containing tourmaline.

Garnetiferous Granite.—A granite or granitite containing garnets.

Beresite is a fine grained granite.

Schistose Granite.—See schists, etc., p. XXII.

Subgroup Granitic Effusives (p. XI).

All rocks belonging to this group have a porphyritic (p. XII) or a glassy structure. In the porphyritic forms the ground mass may be glassy, felsitic (p. VII) or even microcrystaline, but the crystals developed in this ground mass (phenocrysts) are those of minerals peculiar to the granite group. The feldspar is usually sanidine, but may be orthoclase or albite. In the glassy forms (obsidians) which contain no crystals, there is nothing to indicate whether they belong here or to the succeeding groups, unless resort is had to color, fusibility, specific gravity or chemical analysis, and they can not be certainly identified then. The names first given are those assigned to neovolcanic (p. XI note), while those inclosed in parentheses belong to the pretertiary (paleovolcanic) forms.

SPECIES.

Nevadite includes all granitic effusives in which porphyritic crystals make at least 50 per cent. of the mass.

Nevadite proper (*Microgranite, Granophyre*) includes those nevadites whose ground mass is microcrystalline.

Felso-nevadite (*Felsophyre* pp) including those nevadites in which the ground mass is felsitic (p. VII),

Hyalo-nevadite (*Vitrophyre* p) including those nevadites whose ground mass is glassy.

Liparite.—includes all granitic effusives whose porphyritic crystals aggregate less than 50 per cent. of the mass.

Liparite proper (*granophyre*) includes those liparites whose ground mass is microcrystalline.

Felso-liparite (*Felsophyre p*) includes those liparites whose ground mass is felsitic.

Hyalo-liparite (*Vitrophyre* pp) includes those liparites whose ground mass is glassy.

General Forms.

With the exception of the first these are rocks in which differentiation has not gone far enough to disclose their mineral composition, and which in consequence cannot be assigned to any one mineral group.

Rhyolite.—A general term whose use covers all granitic neovolcanics.

Felsite—A term applied to any felsitic (p. IX, VII a) acid rock whose phenocrysts are not sufficient to determine the group to which it belongs. They are probably devitrified obsidians. Eurite and Petrosilex are varieties of Felsite.

Obsidian.—A term applied to any glassy acid rock whose phenocrysts are not sufficient to determine its group.

Pumice is and exceedingly porous obsidian.

Marekenite.—An obsidian filled with globules.

Pitchstone.—An obsidian with a resinous luster resembling pitch.

Perlite.—An obsidian consisting of more or less rounded portions having a pearly luster.

Halleflinta.—A rock composed principally of fine granular quartz with some feldspar, and having a banded structure.

Quartzite.—Massive quartz.

NOTE.—A group of granitic effusives called pantellerites is not recognized here because its members cannot be distinguished from those given, without the aid of the microscope.

XV. Syenite Group.

Essential—orthoclase or albite, and mica, or amphibole, or pyroxene.

Accessory—iron oxides, plagioclase, quartz, apatite.

Accidental—titanite, pyrite, olivine, garnet, nepheline, sodalite, spinel, zircon, etc.

Subgroup, Syenitic Intrusives (p. X).

The rocks belonging to this group may be classed as quartzless, or quartz-poor granites, and by increase in the quartz content they grade into granites.

The feldspar is typically orthoclase, but may be albite, and either of these is liable to be transformed into oligoclase. If only a small part is so changed, the oligoclase is recognized as an accessory mineral, but as the change approaches completeness the rock passes over into a diorite.

The mica present is usually biotite, but may be any other variety.

Hornblende is the typical associate of orthoclase in these rocks, but is often wholly or in part replaced by either biotite or augite.

Hornblende Syenite, Vosgesite, in which the predominating minerals are orthoclase and hornblende, with or without biotite or augite. The forms occurring in veins are called Vosgesites.

Augite Syenite or Monzonite in which the predominating minerals are orthoclase and augite. In this form the orthoclase is often replaced in part by more basic feldspars, and more of the basic minerals are usually present.

Mica Syenite, Minnette in which the predominating minerals are orthoclase and biotite, with or without a little hornblende. The word minnette is usually given to forms occurring in veins and dykes, while the more massive forms are called syenite.

Syenite Porphyry.—This name is given to such syenites as have large crystals of either of the constituents imbedded in a matrix of finer crystals.

Schistose Syenites. See schists, etc. (p. XXII).

Subgroup Syenitic Effusives (p. XI).

NOTE.—The names first given are those assigned to neovolcanic (p. XI note) forms. Those in parenthesis belong to paleovolcanics.

The syenitic effusives belong to one general group, the trachytes, which have the syenitic minerals developed as porphyritic crystals (phenocrysts) in a ground mass which may be microcrystalline, felsitic, or glassy. Owing to the large amount of feldspar in the matrix, many trachytes have a peculiar rough feel, and these forms may often be distinguished by this alone. The trachytes vary widely in color and general appearance, in consequence of variation in the amount of accessory minerals which they carry. The character of these accessories is often indicated in the name.

NOTE.—A group called pantellerites will not be considered here because they cannot be distinguished from the trachytes without recourse to the microscope.

Trachytes (Orthophyre, Keratophyre) including all forms which have sanidine or orthoclase, with biotite, hornblende, or augite developed as porphyritic crystals. The pretertiary forms are called orthophyres when orthoclase is present, and *keratophyres* when its place is taken by albite. Special names are assigned certain forms on account of some peculiarity in structure or composition. A few of these are indicated below.

Phonolite Trachyte includes those trachytes which contain as accessories considerable amounts of sodalite, acmite or aegerine.

Andesite Trachyte includes those trachytes which contain a considerable percentage of the dark iron-bearing minerals.

Domite includes trachytes which have much plagioclase as an accessory. They connect the trachytes with the andesites.

Hyalo-trachyte includes all those which have a glassy matrix.

General Forms.

Obsidian.—See under granite group (p. XIV).

Felsite.—See under granite group (p. XIV).

XVI. Elaeolite Syenite Group.

Essential.—Orthoclase, elaeolite or nepheline, with hornblende, augite or mica.

Accessory.—Plagioclase, iron oxides, apatite, sodalite, cancrinite, zircon.

Accidental.—Tourmaline, spinel, melanite. wollastonite ,perovskite, olivine, etc.

Subgroup, Elaeolite Syenite Intrusives (p. X).

The members of this group are essentially syenites in which much (not all) of the orthoclase is replaced by elaeolite.

Quartz is never present except as an accidental secondary product, and then only in small amounts. The elaeolite is occasionally replaced in part by sodalite, nosean or leucite.

Elaeolite Syenite includes all typical members of this group.

Foyaite includes those elaeolite syenites which contain a considerable proportion of hornblende or augite.

Pulaskite a variety rich in hornblende.

Miascite includes those elaeolite syenites which are rich in biotite.

Sodalite Syenite, *Ditroite* includes those elaeolite syenites which are rich in sodalite.

Nosean Syenite contains much nosean in addition to the typical minerals.

Leucite Syenite contains much leucite in addition to the typical minerals.

Zircon Syenite is elaeolite syenite rich in zircon.

Schistose Elaeolite Syenite, see schists, etc., p. XXII.

Subgroup, Elaeolite Syenite Effusives (p. XI.)

This class includes all crystallines which have sanidine and nepheline as phenocrysts in a microcrystalline, felsitic, or glassy ground mass. Other minerals as hornblende, augite, mica, etc., may appear as phenocrysts.

In the older occurrences the sanidine may be replaced by orthoclase and the nepheline by elaeolite.

Phonolite. This is the typical member of the group, and hence its description is that given above.

Leucitophyr includes those phonolites in which a portion of the nepheline has been replaced by leucite.

Nosean Phonolite includes those phonolites which are rich in nosean.

Hyalo-phonolite includes the glassy phonolites.

General Forms.

Obsidian. See under granite group (p. XIV). The glasses of this group gelatinize with HCl. This is due to the presence of nepheline.

Felsite. See under granite group. Those felsites which belong here would of course carry no free silica.

XVII. Diorite Group.

Essential—Oligoclase with hornblende, augite, or biotite, and with or without quartz.

Accessory—labradorite, rhombic pyroxene, apatite.

Accidental—pyrite, zircon, garnet, iron oxides, orthoclase, etc.

Subgroup, Dioritic Intrusives (p. X).

This group may be subdivided into those which are quartz bearing and those which are quartz free. The quartz-bearing forms resemble granites, except that the feldspar is oligoclase instead of orthoclase, and that their accessory and accidental minerals are of a more basic type, and hence the rocks are generally darker colored. By a transformation of orthoclase into oligoclase (p. VI) granite passes into diorite. Intermediate forms are often found.

The quartz free forms bear the same relation to syenites which pass over into them in the same way.

In the more basic forms the oligoclase is more or less replaced by labradorite, showing the near relationship of these rocks to those of the next groups.

Diorite Proper. Diorite Porphyrite includes all quartz free diorites.

Hornblende Diorite, *Camptonite* includes all diorites whose principal ingredients are oligoclase and hornblende. Those which occur in veins are called camptonites.

Augite Diorite includes all diorites whose principal ingredients are oligoclase and augite.

Mica Diorite, *Kersantite* includes all diorites whose principal ingredients are oligoclase and biotite. Those which occur in veins are called kersantites.

Quartz Diorite, Quartz Diorite Porphyrite includes all quartz-bearing diorites.

Quartz Hornblende Diorite—hornblende diorite with quartz.

Tonalite a variety containing quartz, mica and hornblende.

Quartz Augite Diorite—augite diorite with quartz.

Quartz Mica Diorite—mica diorite with quartz.

Schistose Diorite, see under schistose rocks (p. XXII).

Subgroup, Diorite Effusives (p. XI).

These include all crystalline rocks of porphyritic (p. XI) structure, in which the phenocrysts are oligoclase with horn blende, augite, or mica, and with or without quartz. The ground mass may be microcrystalline, felistic or glassy.

NOTE.—The names first given apply to neovolcanics (p. XI, note). Those in parenthesis apply to pretertiary (paleovolcanic) forms.

Andesite (Porphyrite) includes all forms in which oligoclase, with hornblende, augite or mica, but no quartz, appear as phenocrysts.

Hornblende Andesite includes those forms with oligoclase and hornblende.
Augite Andesite includes those forms with oligoclase and augite.
Hyalo Andesite includes all glassy forms.

Dacite (Quartz Porphyrite) includes all forms in which oligoclase with hornblende, or augite, or mica, *and* quartz appear as phenocrysts

Dacite Proper includes forms with a microcrystalline ground mass.
Felso-dacite includes forms with a felsitic ground mass.
Vitrophyric Dacite includes forms with a glassy ground mass.

General Forms.

Odsidian includes the glasses of the more acid diorites, as well as those of the preceding groups. The dioritic obsidians can only be distinguished from those of the preceding groups by their darker color, greater fusibility and specific gravity.

Tachylite.—The glasses of the more basic andesites, with those of the following groups, are called *Tachylites.*

XVIII. Gabbro Group.

Essential—labradorite or anorthite, and pyroxene.

Accessory—olivine, quartz, biotite, iron oxides, apatite, chlorite, serpentine.

Accidental—oligoclase, orthoclase, pyrite, hornblende, chromite, chalcopyrite.

NOTE.—The rocks composing this group have never been satisfactorily arranged. The limitations of the group itself are matters of dispute. Some authors would limit the group to rocks carrying plagioclase (oligoclase, labradorite or anorthite) and diallage, or rhombic pyroxene, placing those carrying other forms of pyroxene in another group. Others would put both these and the peridotites in a single group, etc. The definitions of the various species are not much more satisfactory than those of the group. The classification and definitions which follow, while not perfectly satisfactory, seem, on the whole, to be the best we can offer.

NOTE.—The members of the gabbro group are peculiarly liable to decomposition. In all decomposed rocks search should be made for the original minerals and the rock determined from them.

Subgroup, Gabbroic Intrusives (p. X).

Gabbro, including forms whose principal constituents are labradorite or anorthite, and diallage. Ophitic structure is common but not essential.

Hornblende Gabbro, including gabbros in which the diallage is in part replaced by hornblende.

Olivine Gabbro, including all gabbros which contain much olivine.

Norite, including forms whose principal constituents are labradorite or anorthite, and enstatite or bronzite.

Olivine Norite including all varieties which carry much olivine.

Hypersthenite, including forms whose principal constituents are labradorite or anorthite and hypersthene.

Diabase, including forms whose principal constituents are labradorite or anorthite, and augite or some pyroxene not included above. Notice that this includes only intrusive rocks, not paleovolcanics.

Olivine Diabase includes all diabases which carry much olivine.

Variolite a variety containing round pea-like bodies in a fine ground mass.

Troctolite includes diabases in which olivine exceeds quartz.

Quartz Diabase includes all diabases which carry much quartz.

Proterobas a variety containing quartz and hornblende.

Corsite—a name applied to those diabases in which the dominant feldspar is anorthite.

Schistose Gabbros. See schists, etc. (p. XXII).

Subgroup, Gabbroic Effusives (p. XI).

NOTE.—The names given first apply to neovolcanic forms, those in parenthesis to paleovolcanics.

Basalt (Augite Porphyrite, Diabase Aphanite) includes forms in which the prominent phenocrysts are labradorite or anorthite, and augite.

NOTE—The highly crystalline basalts which do not contain much glass are called Dolerites.

Olivine Basalt (*Melaphyre*) includes those basalts which carry much olivine.

Hyalo-basalt (*Augite Vitrophyrite*) includes basalts whose ground mass is glassy.

General Forms.

Anamesite, *Aphanite* includes all basic felsitic rocks whose phenocrysts are too few to place them in the foregoing species.

Tachylite includes all basic glasses.

Trap is a term sometimes applied without distinction to dioritic or gabbroic effusives.

XIX. Theralite Group.

Essential—plagioclase, and nepheline or leucite.

Accessory—leucite, hornblende, augite, biotite, olivine.

Accidental—iron oxides, picrolite, spinel, serpentine, mellilite, sodalite, hauyne, etc.

Subgroup, Theralitic Intrusives (p. X).

Theralite includes all the members of this group which have been positively identified up to the present time. The rock consists of plagioclase and nepheline, with augite,biotite, sodalite, hauyne, olivine and iron oxides.

Subgroup, Theralitic Effusives (p XI).

Tephrites include all porphyritic members of this group which do not contain much olivine.

Nepheline Tephrite includes tephrites in which leucite is not a prominent ingredient.

Nepheline Leucite Tephrite includes tephrites in which both nepheline and leucite play the role of prominent ingredients.

Leucite Tephrite includes tephrites in which nepheline is not a prominent ingredient.

Basanites include all porphyritic members of this group in which olivine is prominent.

Nepheline Basantites includes those basanites in which leucite is not prominent.

Leucite Basanite includes those basanites in which leucite is prominent.

Theralitic Glass. See tachylite (XXVIII) and obsidian (p. XVI).

XX. Nepheline Leucite Group.

Essential—pyroxene with nepheline or leucite.

Accessory—biotite, hornblende, olivine, iron oxides, plagioclase.

Accidental—sodalite, hauyne, nosean, garnet, mellilite, etc.

Subgroup, Nepheline Leucite Intrusives (p. X).

None are known.

Subgroup, Nepheline Leucite Effusives (p, XI).

Nephelinite includes all olivine-free members of this group in which nepheline largely predominates over leucite.

Nepheline Basalt includes olivine-bearing nephelinites.

Leucitite includes olivine-free members of this group, in which leucite predominates over nepheline.

Leucite Basalt includes olivine-bearing leucitites.

Nepheline Leucite Glass. See tachylite (p. XVIII) and Obsidian (p. XVI).

XX. Peridotite Group.

Essential—absence of quartz, feldspar, nepheline, and leucite as prominent ingredients.

NOTE.—Rocks whose prominent minerals are plainly decomposition products do not necessarily fall in this group. In such rocks search should be made for the *original* minerals, and the rock classified by their aid.

Peridotitic Intrusives (p. X).

Dunite includes rocks consisting principally of olivine, with some chromite and picotite.

Picrite includes rocks whose principal components are olivine and augite, with some hornblende and biotite.

Wehrlite includes rocks whose main ingredients are olivine, diallage, and hornblende.

Hartzburgite includes rocks whose principal ingredients are olivine and enstatite.

Lherzolite includes hartzburgites which carry diopside and picotite.

Cortlandtite includes rocks whose principal ingredients are olivine and amphibole.

Eulysite includes rocks formed, for the most part, of augite and garnet.

Pyroxenite includes rocks whose main ingredients are bronzite and diallage.

Eclogite includes rocks whose main components are omphacite and garnet, with sometimes cyanite and muscovite.

Amphibolite—a rock consisting principally of amphibole.

Schistose Peridotitics. See p. XXII.

Subgroup, Peridotitic Effusives (p. XI).

Picrite Porphyrite includes porphyritic rocks whose phenocrysts are mostly olivine or augite.

Limburgite includes porphyritic rocks whose phenocrysts are augite, magnetite, and olivine.

Augitite includes olivine free limburgites.

Alnoite includes rocks composed of mellilite, with much augite and biotite.

Mellilite Basalt includes rocks composed mostly of mellilite, but with some augite and biotite.

NOTE.—Occasionally rock masses occur which are principally or entirely made up of a single mineral. In such cases the rock takes the name of the mineral, as *Tourmalinite*, *Garnetite*, etc.

XXII. Classification of Schistose Rocks.

The separation of the members of this group from other rocks is based entirely upon a single physical character, viz.; a tendency, real or apparent, to split along certain well-defined planes. If this one characteristic were disregarded, they would all fall naturally into one or other of the groups given under crystalline or fragmental rocks. Each of the mineral groups described above has its schistose representatives, the schistosity having been developed by the processes described under p. VI and VIII. Hence we have

Granite Gneiss, *Granite Schist*, *Syenite Gneiss*,
Syenite Schist, *Diorite Gneiss*, *Diorite Schist*,
Gabbro Gneiss, *Gabbro Schist*, *etc.*
Peridote Gneiss, *Peridote Schist*,

Such a grouping of the schistose rocks would be exceedingly convenient. (It is actually used in some cases, as indicated below) and would obviate the necessity for further classification if the intense chemical metamorphism (p. VI), which often accompanies (p. VIII) the development of schistosity, did not, in many cases mask the mineralogical composition of the original rock. In fact, the new minerals, so added, often exceed in abundance those considered essentials in the rock from which the schist was derived. It is for this reason that the schistose rocks are usually separated from their relatives, and classified on a different basis.

As will be seen from (p. VIII a, b, c and d) the schistose rocks may be divided on genetic grounds into three great groups, viz.: *Gneisses*, *Slates*, and *Schists*, which will need but little characterization in addition to what is given in the paragraphs indicated. These groups are subdivided on the basis of prominence of ingredients, each species taking the name of that mineral which is most prominent among its constituents. A mineral is considered prominent (*a*) when it is much more abundant than its associates, (*b*) when its crystals are larger, or more brightly colored, or possess some other characteristic which makes them conspicuous.

The student is advised, after placing the specimen under one of the groups, *Gneiss*, *Slate* or *Schist*, to follow the classification first given, when the relative importance of the minerals in the original rock has not been seriously interfered with by the changes which it has undergone; but in cases where chemical metamorphism has been severe, he should use the second. For example, if the composition of a schistose rock is plainly that of a diorite, call it a *diorite gneiss*, *diorite slate or diorite schist*, as the case may be, prefixing as an adjective, where it seems best, the name of any secondary mineral which may be prominent, (*Garnetiferous diorite schist*), but when the new minerals introduced by metamorphism are so abundant as to mask the original composition, or make it difficult to assign the rock to any of these groups, take the other classification, and call it a *mica schist*, *fibrolite gneiss*, *quartz schist*, *hornblende slate*, etc.

Subgroup, Gneiss.

The origin of gneiss has been described under p. VIII a and b. It will be noticed that two grades are recognized, (*a*) *granitoid gneiss* which must be called an incipient gneiss, and (*b*) *true gneiss*.

Granitoid Gneiss includes rocks whose composition is closely similar to that of some member of the mineral groups already described, and which could readily be assigned to one of these groups, if schistosity were neglected.

In these rocks again, while the rearrangement of the particles has imparted a hairy fibrous appearance, there is no distinct banding, and no real tendency to split along definite planes. They are divided into

Granite Gneiss,
Syenite Gneiss,
etc.
Diorite Gneiss,
Gabbro Gneiss,
etc.

When some secondary mineral is present in sufficient quantity to be worth of mention, its name may be prefixed to those given above.

True Gneiss.

When incipient fractures, together with vigorous chemical metamorphism, have imparted a distinctly banded structure, and secondary minerals have become so numerous, or so abundant, as to raise a doubt concerning the mineral group to which the rock should be assigned, the above method of classification is abandoned, and the rock is named for its most prominent mineral (see above). Some of the more common forms are

Muscorite Gneiss,
Biotite Gneiss,
Protogine Gneiss,
Cordierite Gneiss,
Chlorite Gneiss,
Epidote Gneiss,
Magnetite Gneiss,
ets.
Hornblende Gneiss,
Augite Gneiss,
Garnet Gneiss,
Albite Gneiss,
Fibrolite Gneiss,
Scapolite Gneiss,
Graphite Gneiss,
etc.

Subgroup, Slates and Phyllites.

The origin of rocks belonging to these two groups is given under p. VIII c. They are much less common than either the gneisses or the schists, and for obvious reasons, are almost exclusively confined to fine-grained rocks. A very large percentage of the known deposits of slates have been derived from metamorphism of argillaceous sedimentaries (p. XXIV). Examples are

Clay Slate,
Diorite Slate,
Sericite Slate,
etc.
Hornblende Slate,
Chlorite Slate,
Ottrelite Slate,
etc.

Subgroup, Schists.

The schists represent in a more pronounced form, the action of the forces which produce gneisses, slates and phyllites (p. VIII d). Here, as in gneiss, are found forms which readily fall into the mineral series of the crystalline rocks, except for their schistosity. Such forms take the name of the group under which they naturally fall, as

Granite Schists
Diorite Schists,
etc.
Syenite Schists,
Gabbro Schists, (Zobentites)
etc.

In other cases, where chemical metamorphism has produced more change, they take the name of the most prominent mineral, as

Mica Schist,
Quartz Schist,
Graphite Schist,
Chlorite Schist.
Uralite Schist,
Dolomite Schist,
Ottrelite Schist,
Chiastolite Schist.
Tourmaline Schist,
Hornblende Schist,
Paragonite Schist,
Talc Schist,
Actinolite Schist,
Calc Schist,
Serpentine Schist,
Staurolite Schist,
Sericite Schist,
etc.

NOTE.—Itacolumite is a peculiar form of mica schist, which is slightly flexible in thin sheets, sometimes called *Flexible Sandstone.*

Each of the above may become the foundatiion for a new series, owing to the presence of a large quantity of some mineral other than that which gives the schist its primary name. For example, the extreme form of amphibole schists, which is often called amphibolite, is subdivided into

Plagioclase Amphibolite,
Zoisite Amphibolite,
etc.
Garnet Amphibolite,
Epidote Amphibolite,
etc.

Certain rocks, which have been described in the foregoing pages, occasionally take on a schistose structure. In such cases, it is the custom to retain the specific name of the rocks with or without the word schistose prefixed. Examples are

Halleflinta,
Granulite,
Olivine Felsite,
etc.
Augitite,
Eclogite.
Garnet Felsite,
etc.

XXIII. Classification of Fragmental Rocks.

The limitations of this group are given in paragraph IV. From them it will be seen that all rocks formed through the breaking down of crystallines (p. III) whether by the action of chemical, physical, or mechanical forces, fall under this group. It will further be seen that *all mineral masses, whose components are salts of acids other than silicic* fall here, and that rocks composed entirely of silicates are also regarded as belonging to this group, if they can be shown to have been derived from the breaking down of older silicates. Again it will be seen that the physical condition of a rock, whether crystalline or not, has no influence in deciding whether it shall be placed in this or the preceding series. A fragmental rock may be completely crystalline or completely amorphous, but must *not* be a mass of silicates which have come into their present condition through fusion and cooling, unless, during the process of cooling, they were blown into fragments by the bursting of bubbles of superheated steam.

In most cases the members of each series fall readily into their proper places, but in the case of rocks like the arkose sandstones, (p. XXIV b) which are formed by the crushing of some crystallines, and in which the transportation and cementation has been accomplished without much wear of the fragments, it is often difficult to decide where they should be placed. A like difficulty is experienced in the case of true crystallines in which chemical metamorphism has produced large changes, often imparting a facies closely resembling that of some fragmentals, but has not gone far enough to effect their complete decomposition. In such cases determination by hand specimens is often impossible, and search must be made in the field for unaltered portions, which will lead to a correct identification.

Owing perhaps to the great diversity in form and composition, presented by fragmental rocks, and the frequency with which the most distinct types grade into each other, a thoroughly satisfactory classification has not yet been proposed; that which follows seems to come nearest satisfying all conditions. All fragmental rocks may be divided into *Mechanical Fragmentals* (p. IV a), *Volcanic Fragmentals* (p. IV c), *Chemical Sedimentaries* (p. IV b), *Homogeneous Crystallines* (p. IV d) and *Carbonaceous Sedimentaries* (p. IV e).

XXIV. Mechanical Fragmentals (p. IV a).

Including all rocks which are composed of particles of preexisting rocks, whether these particles were set free by the decom-

position of the rocks from which they are deriveo, or by the action of frost or abrasion.

In paragraph IV attention is called to the fact that all rocks contain a considerable percentage of water. This water is constantly in motion, and by virtue of the materials that it carries in solution, it reacts chemically upon the less stable portions of the rock, removing the soluble ingredients and leaving the more insoluble ones in a loose, incoherent mass. When water which has entered and filled a crack or crevice in a rock, freezes, its expansion breaks off grains, or even fragments of considerable size. A rock may be entirely broken up in this way. The roots of plants find their way into the joints and crevices, or even eat channels into the solid rock, and by their expansion break off large fragments. It is in one or more of these ways that solid rocks are reduced to masses of fragmental material.

After the rock has been broken down, running water picks up the particles, and, dragging them along its bed, uses them as tools to break off others, which, in turn, are added to its load and give it more wearing power. *This load it carries until some slacking of its current causes it to drop the coarser or heavier fragments. A further retardation brings down those of the next grade of fineness, and so on until all the material has been assorted and deposited in beds, according to the size and weight of the particles. The masses of loose material accumulated in this way are usually cemented into solid rock by the precipitation of matter carried in solution by the water, and this precipitated material often forms more than one-third of the mass.

We see then that the material which makes up the mechanical fragmentals may be derived either by chemical action, or by fracture and wear, but is always assorted by moving water. If the particles were set free by decomposition, a new rock formed from them will contain only the more resistant ingredients of the original rock, but if they were derived by fracture, each fragment will be likely to contain the essential elements of the original. When the particles are transported to a considerable distance from their place of origin, they are likely to be mixed with those of other rocks, and if the distance be great, the sediment will probably contain materials derived from many kinds. If

---

*The carrying power of a current varies as the sixth part of its velocity.

the distance be not great, it is often possible to trace sediments to their origin. Again, if the fragments are large, or are composed of some peculiar material, the same thing may be done, but as a rule complex sediments give us little information as to their exact source, although they may tell us much about the direction and strength of the currents that bore them.

The mechanical fragmentals are subdivided into *soils*, *arenaceous rocks*, *argillaceous rocks*, *steatitic rocks*, and *ores*.

(XXIV a). **Subgroup, Soils.**

Under this term are included all rocks formed by the admixture of fine particles of broken-down rock, with more or less decomposing organic matter (conditions which enable them to supply the needs of growing vegetation). The rock fragments, by their further decomposition, set free certain chemical ingredients which are essential to the well-being of the plant, and also give to the soil that porosity which increases the movement of water, by which the decomposition is effected, and the moisture is left in proper condition for absorption by the roots of plants. The organic matter, besides supplying certain elements directly to the plant, provides humic acids, which are such agents in the decomposition of rock fragments, when brought in contact with them by circulating water, and also act as middle men when conveying gases from the atmosphere to the plant. They are divided into *soils of disintegration* and *soils of transportation*.

Soils of Disintegration include all soils formed in situ, that is, by the decomposition of the rocks which they overlie. If a pit be dug in such a soil the size of the rock fragments will increase as we descend, until the solid rock is reached. Although an occasional soil formed in this way may be as fertile as any transported soil, they will usually contain but a relatively small number of mineral ingredients, and hence are adapted to but a small range of crops, and are soon exhausted. In other cases they are so dense as to require a large admixture of foreign matter to give them the necessary porosity. Such soils are divided into

Loam, which contains large quantities of humus or decaying vegetation.

Marl, which carries large amounts of both clay and lime.

Argillaceous Soils, which consist principally of clay.

Arenaceous Soils, which carry a large portion of sand.

Soils of Transportation. The materials of which these soils are composed were formed, in part, by the decomposition of rocks in situ, and in part by abrasion on stream and glacier beds, but all have been transported from their place of origin to their present position through the agency of wind, water, or ice. As the drainage basins of rivers and glaciers include many different kinds of rock, the materials which their streams gather are of the most diverse character, and contain a wide range of elements of fertility, intimately mixed. It is for this reason that transported soils are generally much more fertile, and better adapted to a varied agriculture, than those formed in situ. Their subdivisions are the same as those given under soils of disintegration.

(XXIV b). **Subgroup, Arenaceous Rocks.**

Comprise all those which are formed of undecomposed fragments of other rocks, whether loose or united by a cement. They are divided into *Sand*, including all loose forms, and *Sandstone*, including those whose particles are united by a cement.

Sand. When crystalline rocks are broken down through the action of earth water (p. XXIV a), their more readily attackable mineral ingredients are decomposed, and a portion, at least, of the silicic acid which they contained is set free and crystallizes as quartz. Some times the quartz molecules build independent crystals with perfect outlines; at others they attach themselves to the loosened quartz grains of the original rock [which, it will be remembered, were last to crystallize, and hence were prevented from taking on true crystal forms (p. X, XIV)], and transform them into crystals. With the crystals so formed are mixed all the more resistant minerals of the original rocks, and fragments broken from these rocks, as well as the finely divided insoluble products of decomposition. Running water separates these crystals and fragments from the finely divided materials and deposits them as beds of sand. Sand so formed must contain all the more stable minerals of the crystalline rocks from which it is derived, and if it has been transported over beds of fragmental rocks, it will also contain a large or small percentage of fragments broken from them. The larger pieces will have their angles rounded, partly by the wear of particle against particle, and partly, more largely perhaps, by chemical action, the acids of earth water producing more effect on the thin edges, than on the mass. The smaller particles, on the other hand, suffer little wear; in fact, they may be transported hundreds of miles without perceptible blunting of their angles, and hence their rounding must be principally due to chemical action. Wind-driven sands seem much more likely to have their angles rounded by wear than those which have been carried by water. Sands are divided into

Gravel, which comprises all the coarser deposits.

Sand, which includes all deposits of finer material.

The subdivisions of each of these groups are based on the prominence of certain ingredients, or the occurrence of unusual minerals; hence there may be many varieties of each group. Examples are

Quartz Sand,
Magnetite Sand,
Granite Gravel,
Limestone Gravel,
Glauconite Sand,
Calcareous Sand,
Dioritic Gravel,
Cupriferous Gravel,
Micaceous Sand,
Garnet Sand,
Flint Gravel,
etc., etc.

NOTE.—Deposits of pure quartz sand are rare and very valuable. Such material is used in the manufacture of the best grades of glass and porcelain, and of refractory brick and furnace linings. It is also much used for cutting, grinding, and polishing. The mixed sands and gravels are principally used in the manufacture of concretes and mortars, and for road metal.

Sandstones are merely beds of sand whose grains are united by a cement. The cementing substance has been chemically precipitated, and sometimes forms a considerable percentage of the mass. It is usually carbonate of lime, carbonate of magnesia, oxide of iron, or silica, but may be any substance, carried in solution, which is capable of holding the grains together. They are divided according to the form and size of their constituent fragments into

Agglomerates, whose components average six inches or more in diameter.

Conglomerates whose components are smaller than those of the agglomerates, and rounded.

Breccias, whose components differ from those of conglomerates in being angular.

Grits. Compact even-grained rocks whose components are smaller than those of a conglomerate, and are sharp angled.

A coarse sandstone is often, but wrongly, called a grit.

Sandstone comprises all the finer grained members of this group.

Each of the above groups is divided into species on the basis of its cementing material. Thus we may have

Calcareous Conglomerates
Ferruginous Conglomerates,
Siliceous Conglomerates,
etc., etc.

Calcareous Sandstones,
Ferruginous Sandstones,
Siliceous Sandstones,
etc., etc.

Each of these is often divided into varieties on the basis of its predominant ingredient, or the occurrence of some unusual mineral.

Micaceous Sandstone,
Hematitic Sandstone,
etc., etc.

Jasper Conglomerate,
Iron Conglomerate,
etc., etc.

Special forms are:

Grindstone Grit. A sharp, even-grained sandstone, whose grains are rather loosely cemented. If the particles are too firmly united the stone is apt to glaze.

Millstone Grit. A sharp, even-grained, siliceous sandstone whose grains are firmly cemented. These stones glaze and must be frequently dressed. They must not be confused with buhrstones, which will be described under chemical fragmentals.

Firestones. Purely siliceous sandstones, which may be cut into thin slabs for furnace linings, etc., and will withstand great heat.

Freestones. Sandstones which work equally well in either direction, showing no tendency to split. Such stones are rare. It is always safest to lay a sandstone on its natural bed.

Arkose. A sandstone composed of fragments of some crystalline rock, which have suffered little or no alteration. They are often difficult to distinguish from the corresponding crystallines.

Greensand. A sandstone containing much glauconite.

Itacolumite. See under schists.

NOTE.—Pure sandstones are seldom met with. They usually contain a percentage of clay or carbonate of lime among their detrital materials, and, as this percentage is variable, sandstones pass by regular gradations into shales or limestones.

(XXIV c.) **Argillaceous Rocks.**

Are formed of the finer materials resulting from the decomposition or wear of older rocks. The basis of these rocks is kaolin or some hydro-aluminous silicate, but they often contain a large percentage of other substances, chiefly small fragments of the rocks from which their ingredients were derived, but partly secondary minerals formed during the decomposition of these rocks. Occasionally a hydro-mica, which is, perhaps, the most common of these secondary minerals, seems to almost replace the kaolin.

Argillaceous rocks may be formed by the decomposition of older rocks in situ, but the materials have usually been carried some distance from their place of origin. In the latter case the ingredients of the parent rock are mixed with quantities of rock flour picked up by the transporting water from the rocks over which it flows. Hence transported clays are usually much more impure than those formed in situ. But when these same clays have, as in the case of the beds which underlie many of our coal seams, formed the soil that supported heavy growths of plants, which abstract more or less of the alkalies or alkaline earths, as well as iron (materials which act as fluxes), they are sometimes rendered pure enough for the manufacture of high-grade porcelain, and often refractory enough for the best fire brick.

The classification of argillaceous rocks is based on their hardness, purity, and the uses made of them. They are primarily divided into *Clays*, *Shales*, and *Slates*.

Clays are loose or uncompacted masses of more or less pure kaolin, which, as a rule, are highly plastic either in the natural state or after grinding. When subjected to a higher temperature they lose their water of crystallization (combined water, water of hydration), shrink, and become permanently non-plastic. The purer kinds are very refractory, and are used for the manufacture of fire-brick and other articles which are required to withstand higher temperatures. Wares made from such clays are always porous (wares made from any clay will be porous if burned at a sufficiently low temperature), but if they contain a proper percentage of alkali, alkaline earth, or other fluxing material, they will undergo incipient fusion (vitrification) at about a red heat, and become exceedingly hard and nonabsorptive. If the temperature is raised still higher they will melt and flow. Many clays require the admixture of a large percentage of silica to overcome their tendency to shrink, crack or undergo deformation while burning.

Clays are divided as follows:

China Clay is theoretically a pure kaolin, but may contain a large percentage of fine-grained silica and a small percentage of alkali without injury. It must not contain coloring matters other than organic substances if white ware is desired. If silica and alkali are not present, they are added during manufacture, the first to prevent cracking and deformation through shrinkage, the second to give the delicate semi-transparency which is so highly prized.

Fire Clay resembles china clay except that it should contain no (or but little) alkali, and may carry some coloring matter. It is practically a mixture of pure kaolin and silica, both of which are capable of resisting very high temperatures.

Terre Cotta Clay is one which takes a uniform and pleasing color on burning.

Fuller's Earth. A fine grained, non-plastic, highly siliceous clay, which is used by weavers to extract the oil from woolen goods.

Brick and Tile Clays include all the coarser, more impure varieties, which carry enough kaolin to hold them together. Tile clays always should carry enough silica or organic matter to make them very porous when burned. Brick clay should contain such a percentage of flux as will insure a wide range of temperature between the vitrifying and fusing points. The proper composition is frequently obtained by mixing clays from two or more deposits with some sand.

Argillite is clay that has been baked by being brought in contact with heated rocks.

Loam. A highly siliceous clay with more or less organic matter. See under soil.

Loess. A fine, *even-grained*, highly siliceous, light yellow clay (the silica often exceeds the kaolin) which may or may not carry carbonate of lime as a result of the decomposition of shells. The definition and origin of löess has been and still is a battle ground. The only distinctive characteristic on which all agree is its fineness and evenness of grain. "One can scarcely feel the grains with the finger."

Till, or Boulder Clay, is a glacial deposit consisting of clay mixed with rounded, often striated pebbles of many different kinds.

Wacke is formed by the decomposition of many kinds of rocks. It consists of clay enclosing many fragments of the minerals of which the original rock was composed. Grey wacke is the most common form.

Paint Pigments are fine, even-grained clays which carry a large percentage (15-80) of metallic oxide.

Mudstone or *Claystone* is a clay whose particles have been cemented by the precipitation of lime or iron between them, but which is not schistose. It forms the connecting link between *clay* and *shale*.

Shales include argillaceous rocks whose ingredients have been cemented by the precipitation of material carried in solution, and in which a schistose structure, roughly parallel to the bedding, has been developed, partly by pressure and shrinkage during consolidation, and partly by an alternation of coarser and finer sediments, due to slight changes in the current while the material was being deposited. The cement is usually lime or iron, but may be any other material capable of holding the grains together. *Shales are irregularly schistose parallel to the bedding. Slates are regularly schistose. and the plane of cleavage usually makes an angle with the bedding.* Shales are classified on the basis of their cementing material, or their color, or the presence of any unusual ingredient. Examples are:

Ferruginous Shale,
Gray Shale,
Carbonaceous Shale,
Alum Shale,
etc., etc.

Calcareous Shale,
Black Shale,
Oil Shale,
Bituminous Shale,
etc., etc.

Shales graduate into limestones, sandstones, or clay ironstones according to their varying content of carbonate of lime or magnesia, sand or iron.

Clay slates (p. VIII b, c, XXII) belong to the class of homogeneous crystallines (p. IV d, XXVII), but are mentioned here in order to make their relationship clear, and to cover the relatively rare cases, in which a slaty structure has been impressed on argillaceous rocks without much crystallization. They are metamorphic shales or clays.

(XXIV d.) **Steatitic Rocks.**

As kaolin is the basis of argillaceous rocks, so talc, or some hydro-magnesian silicate, is the principal ingredient of the steatitic series. These rocks are composed of debris of the more basic crystallines, and may be formed in situ or transported. As aluminous and magnesian minerals are intimately mixed in most crystallines, the products of their decomposition, kaolin and talc, usually occur in their debris, and predominance of one or the other must point out the series to which a given deposit belongs. Steatitic rocks have the same fire-resisting properties as those formed of kaolin, and may, in general, be used for the same purposes, but are better non-conductors of heat, and hence are largely used in fire-proofing. The rocks of this series are soft and have a greasy feel. Those most used are:

Talc. A soft, greasy, even-grained, grayish or greenish rock, which is a nearly pure hydrous silicate of magnesia. It is used, in the form of a powder, as a lubricant, paint pigment, filler for paper, etc., and as an adulterant.

Meerschaum. A loose magnesian rock with the composition of talc, and the properties and appearance of kaolin. When first dug it has a greasy feel and lathers like soap, but soon looses these properties. It is largely used in the manufacture of pipes, porcelain, etc.

Steatite is an impure talc which occurs in heavy deposits. It is a mottled rock with more uneven grain than talc, and is softer and has a more greasy feel than serpentine. It is much used for lining furnaces, making retorts, foot-warmers, cake griddles, etc.

Serpentine is also an impure magnesian rock, harder and with a less greasy feel than steatite. Its colors are red, green and yellow, usually of pleasing tone, and it often takes a fine polish. It is more or less fusible and is decomposed by acids. The serpentines are much used for interior decoration, both pure and when they occur mixed with calcite, as in ophicalcite (green marble) of which Eozöon canadense is a noteworthy example.

Ores. Most ores belong under the class of chemical sedimentaries, but some few arise by concentration through the solution and transportation of the other ingredients of the rock in which they occur. Beds of magnetite are more frequently formed in this way than those of any other ore, and these have in some cases been changed into hematite or limonite.

XXV. Volcanic Fragmentals.

During a volcanic eruption, the superheated steam, which has played so prominent a part in the liquefaction of the rock, suddenly expands, and its bubbles burst with great violence, throwing small portions of the melted rock high in the air. These particles cool as they fall, and often form beds of great thickness in the neighborhood of volcanoes. This material when fresh has a non-crystalline structure, its particles glassy, but through the action of earth-water it gradually comes to contain more or less crystals, which vary in mineral character with the lava from which they arose, and with surrounding conditions (p. XI, XII, XIII). This is especially true of the coarser forms.

They are divided according to their compactness or fineness into *Tufa*, *Trass*, *Puzzuolana* or *Ash*.

Tufa, or Tuff, a term made to include all more or less firmly cemented volcanic fragmentals. Its finer varieties fall under Trass, as described below, and its coarser are *conglomerates* or *breccias* according as the fragments are rounded or angular.

Schalstein is a name given to certain tufas which have accumulated in the ocean, and are in consequence more or less mixed with other sediments. They sometimes contain fossils.

Lappilli includes coarse fragmental materials varying in size from a pea to a walnut.

Trass includes volcanic fragmentals whose constituents are comparable in size to coarse sand, and are more or less firmly cemented.

Volcanic Ash includes masses of loose, finely divided material of volcanic origin. It may be entirely earthy or contain a considerable percentage of minute crystals.

Puzzuolana is volcanic ash which is rather coarse and non-crystalline. It is used in the manufacture of some hydraulic and Roman cements.

The Tufas through the action of ground-water come to contain crystals, which in any given case represent the essential components of some one of the mineral groups described under crystalline rocks, and hence take their name as follows:

Rhyolite-breccia.
Diabase-conglomerates.
Leucite-Phonolite-tuff.
Granite-conglomerate.
Pumice-conglomerate.
etc., etc.

Felsite-tuff.
Phonolite-tuff.
Augite-porphyrite-tuff.
Palagonite-tuff.
Pumice-sandstone.
etc., etc.

XXVI. Chemical Sedimentaries.

Paragraph IV explains how the decomposition of crystalline rocks (p. III) is affected by acids carried in solution by rock-water. These break down the compound silicates, uniting with one or more of their bases. The salts so formed are generally soluble in earth-water, and are carried away by it to other places where changed conditions bring about their precipitation. These same acids, entering into fragmental rocks, dissolve their ingredients also, and the dissolved materials are carried and precipitated in the same way as those derived from crystallines. Under chemical sedimentaries then we include all rocks whose ingredients have come into their present condition by precipitation from solution as noted in p. III c, XI note, or are the resultants of chemical changes wrought on materials so precipitated by earth-water. They are divided, somewhat unscientifically, into *minerals*, *ores*, *siliceous rocks* and *calcareous rocks*.

(XXVI a). **Subgroup, Minerals.**

All deposits of minerals, other than silicates, except as noted below, as well as all masses of silicates whose present condition is plainly due to precipitation from solution, except as indicated in p. III c, XI note, are included here.

Careful study of crystalline rocks will usually reveal the presence in them of minerals, other than silicates. Some of these may have been formed at the time the mass solidified, but it is the growing belief among geologists that most such minerals, as well as ordinary silicates occurring under similar conditions, are secondary minerals (p. VI c. VIII c, d); that is, they have been formed since the consolidation of the rock, through the action of water. If crystals formed in this way are deposited so near the source of their ingredients, it is plain that masses of like materials may be formed wherever conditions for their precipitation are found. It is for this reason that, in the absence of positive evidence of some other mode of formation, all mineral masses other than silicates, and all masses of silicates which were plainly formed by precipitation, except those described under vein-rocks (p. XI. note), are included in the fragmental series. In special cases such a grouping may make it difficult to decide where a given rock should be placed, but in general there will be no difficulty. Let us take an example: Tourmaline is a silicate which in all probability is never formed except through the action of water. If a few crystals of tourmaline occur in a mass of granite, they are considered a part of the granite, and the whole is called tourmaline (or schorl) granite, but if a large mass of tourmaline occurs independently, that is, in some pocket, or under conditions which would cause it to be regarded as an independent rock mass, it would be considered a fragmental rock, and would fall here.

For a classification and description of such minerals see Dana's Text-Book of Mineralogy.

(XXVI b) **Subgroup Ores.**

What has been said under minerals applies as well to ores. All ores, excepting those described in p. XXIV, and the possible, almost hypothetical, volcanic ores, are included here. These ores should be determined as minerals. See table page 64.

(XXVI c) **Subgroup Siliceous Rocks.**

Includes all rocks whose principal component is silica, and which have been deposited from solution. They will be considered in two classes. (1) Those which have been deposited by heated waters. (2) Those which have been deposited from waters at ordinary temperature.

CLASS I. Heat increases the solvent power of water over silica in a marked degree, and if the heated water carries a small amount of alkali, as most earth-waters do, it is able to dissolve silica readily; hence the waters of many hot springs carry much silica in solution and deposit it on cooling. The precipitation is at least aided, perhaps entirely accomplished, by filamentous algæ, which absorb the silica from water as corals do carbonate of lime. The material so deposited is called

Siliceous Sinter, and varies in structure from that which is so soft as to crumble readily between the fingers, to varieties which are as hard as quartzite. In some regions it is deposited so abundantly as to form masses hundreds of feet in height and covering square miles in area. Geyserite is a form deposited by lime springs.

Novaculite is a compact, fine, even-grained sinter, which furnishes our best material for hones and oilstones, such as the "*Arkansas*" and "*Washita*" (Ouachita) stones of Garland county, Arkansas, and the "*Hindostan*" and "*Orange*" stones from Orange county, Indiana. These deposits were probably formed by the metamorphic action of heated waters upon some preëxisting rock, rather than by direct deposition.

NOTE.—Heated waters often impregnate fine-grained mica schists with very minute crystals of some hard mineral like silica, garnet, rutile, etc. Stones so formed also give us some of our best hones and oil stones.

Buhrstones are masses of silica produced in much the same way as Novaculite, but less even in grain and having an open, porous structure. The best are found in the tertiary rocks near Paris, but a German basalt, silicified in a similar manner, ranks nearly as high.

CLASS II. The spicules of sponges, frustules of diatoms, and tests of other silica-secreting organisms, often form beds of considerable thickness in the basins of inland lakes. Such a bed is said to be now forming in Lake Tahoe, and many are known to exist in the lake basins of former geologic periods. The same materials are also deposited with the remains of lime secreting animals and plants in coral reefs and shell banks.

Infusorial Earth includes the loose and relatively pure deposits of this kind, such as are found at Pope's Creek, Maryland, and many other places both in the east and west. The largest deposit yet reported has been cut through by Pitt River in California. It is sixteen miles long, one mile or more wide, and three hundred feet deep. Many deposits of this kind contain 80-90% of infusorial remains.

Infusorial earths are sold as polishing powders under the names Tripoli, Electro Silicon, etc. They are also used as an absorbent in the manufacture of dynamite. Bricks, tiles and lining, which are very refractory and light enough to float on water, are made of them, and used for fireproofing in the construction of vessels.

Flint, Chert, etc., so common in limestones, are formed by the segregation, through solution and redeposition, of the remains of silica-secreting animals and plants, which were deposited with the other materials while the limestones were forming.

(XXVI d). Calcareous Rocks.

Include all those which are, in the main, composed of the carbonates of lime or magnesia, precipitated with or without the aid of organisms. They are, in general, made up of the more or less broken skeletons of corals, spicules of calcareous sponges, shells of mollusks and molluscoids, tests of echinoderms, crustacea, and infusoria, and granules secreted by algae, which are cemented by chemically precipitated lime, iron or silica. Many silica-secreting organisms are found living among those enumerated above, and these add their remains to the accumulating mass. The materials deposited in this way are subsequently segregated by solution and redeposition, and form the layers and nodules of flint and chert so common in limestones. The banks on which the calcareous materials are accumulating, are often swept by currents or waves, which bring sand or clay and deposit it among the fragments. If such invasions are frequent, the rock may contain more of these ingredients than of lime, and hence limestones pass by insensible gradations into siliceous or argillaceous limestones, then into calcareous sandstones or shales. Again, when iron bearing water penetrates a limestone, it not infrequently dissolves the lime and leaves iron in its place In this way the limestone is gradually transformed into a ferruginous limestone, then into a calcareous iron ore. This process of replacement of limestones, not by iron alone, but by various ores, is not at all uncommon. The more common varieties of limestone are

Travertine, including masses of carbonate of lime or carbonate of magnesia deposited by springs or in caverns. It varies in structure from a loose, crumbling mass, to a fine, even-grained, compact rock, capable of taking a fine polish. The massive varieties are often translucent, and are beautifully banded by slight variations in the impurities carried by the water. Such forms are called semi-onyx or Mexican onyx, and are much used in interior decorations. *Calcareous Sinter* is a loose form of travertine.

Shell Limestone is practically a compacted mass of shells or other animal remains, the fragments being of such a size as to reveal their general character. If the remains are mostly of one kind, the rock takes the name of the group to which it belongs.

Examples are: *Coquina* a mass of shells cemented by carbonate of lime.

Bryozoal Limestone.
Fusulina Limestone.
Crinoidal Limestone.
Numulitic Limestone.

Chalk is a fine-grained, loosely compacted limestone made up of the shells of lime-secreting infusoria. Its formation differs from that of other limestones, in that the animals of whose remains it is formed were surface dwellers, and their shells settled to the bottom through considerable depths of water. The hard particles in chalk are usually siliceous nodules formed as described above.

Oolite. Under certain conditions the carbonate of lime held in solution by sea water is precipitated in concentric layers around grains of coral sand or other small particles as nuclei, and the rounded grains so formed are afterward cemented into solid rock. It is not yet settled how large a part certain algæ play in this precipitation, but the evidence seems to indicate that in some cases at least, they are the active agents in the formation. Because the small granules somewhat resemble the roe of a fish, the rock has been called oölite or egg stone. When the grains approach a pea in size, it is called a *Pisolite*, and if still larger *Concretionary Limestone.*

Siliceous Limestone includes those forms which contain a considerable quantity of silica and have a more or less conchoidal fracture.

Hornstone, a fine-grained, highly siliceous limestone.

Cherty Limestone is a siliceous limestone, whose silica has been collected through the agency of water, and deposited in flakes, nodules or bands.

Lithographic Limestone is a fine, even-grained limestone, homogeneous in structure, having a conchoidal fracture, and sufficiently porous to absorb oil or water readily. Limestones having these characteristics are not so very rare, but are usually so badly fractured that only small pieces can be taken from the quarry. Hence, beds which furnish large slabs of good quality are very valuable. Our principal supply at present comes from Bavaria.

Hydraulic Limestone contains a considerable percentage of silica (20-30) and clay (10-20), but if magnesian limestone is employed, the carbonate of magnesia may to some extent replace the clay, if carefully burned.

Argillaceous Limestone contains a large percentage of clay.

Ferruginous Limestone contains much iron oxide.

Ironstone contains more iron and clay than lime.

Rottenstone is derived from the decomposition of a ferruginous limestone, rich in silica and clay.

Magnesian Limestone or **Dolomitic Limestone**. Many of our limestones contain a larger or smaller percentage of carbonate of magnesium. In most cases this was not deposited with the lime, but came into its present position through precipitation by displacement, in much the same way that many iron ores were formed. When the proportion does not exceed fifty per cent, the above names apply.

Dolomite includes magnesian limestones which contain more than fifty per cent. of carbonate of magnesia.

Bituminous Limestone contains more or less organic matter which colors it blue or black. The color is entirely discharged by heat.

Glauconite Marl or **Greensand** is a loose or slightly compacted limestone which carries much glauconite.

Crystalline Limestones.—See below.

XXVII. Homogeneous Crystallines.

Include sedimentary rocks which have been subjected to physical metamorphism (p. VII), and have acquired a crystalline structure. Metamorphic action may induce crystallization in the individual layers of a mass without causing an admixture of the ingredients of the different layers. The result will be a completely crystalline rock of homogeneous composition. Such rocks are to be carefully distinguished from the members of the crystalline series. The more common kinds are:

Quartzite. Metamorphic sandstone; that is, a sandstone which has been flooded with silica-bearing water, and whose ingredients have been enlarged and cemented by the precipitation of the silica. (p. XIV, XXIV c.)

Marble. Metamorphic limestone or dolomite (XXVI d). True marble always has a completely crystalline structure, but as a trade name the word is often made to cover any limestone which will take a polish. True marbles are only found in mountainous or much disturbed regions; the others may occur anywhere.

Ophi-calcite or Ophi-dolomite is a metamorphic mixture of marble and serpentine. It is known as green marble, and is much used for decorative purposes. See under serpentine (p. XXIV).

Clay Slates are clays or slates in which crystallization and lamination have been induced by metamorphism. See under schistose rocks (p. XXII) and mechanical metamorphism (p. VII, also XXIV b), also under shales (XXIV c).

Anthracite is coal which, through metamorphic action, has acquired a semi-crystalline structure. True anthracite has a conchoidal fracture, and usually a brilliant lustre. Much that is sold under the name is semi-anthracite, an intermediate between anthracite and bituminous coal. Such coal has a flat fracture in one or more directions.

Graphite. If graphite is the extreme metamorphic form of coal, which is very doubtful, it falls here.

XXVIII. Carbonaceous Sedimentaries.

Comprise all rocks formed of partially decomposed organic matter. The more common forms are:

Coal.—For a description of the processes by which coal is formed, the student is referred to an essay by Lesquereaux, in the "Annual Report of the Geological Survey of Penna. for 1885," and for a classification of coals, to Dana's Text Book of Mineralogy, p. 545, or Dana's System of Mineralogy, p. 217, or Encyclopedia Brittanica, Vol. VI, p. 45.

Asphalt.—A hardened, oxidized form of petroleum. It is a smooth, brittle, pitch-like mineral, with resinous lustre and conchoidal fracture, and melts at the temperature of boiling water. (See Dana's System of Mineralogy, p. 1017, or Dana's Text Book of Mineralogy, p. 545).

Oil Shale.—A clay shale impregnated with bituminous matter to such an extent that it is capable of yielding mineral oil on distillation, and is much used for this purpose in Australia. It has been referred to under *shales* (XXIV c).

Graphite.—A soft, infusible, black mineral, with greasy feel and lustre, which occurs in schists, traps, quartz veins, limestones, coal beds, many basic rocks, and meteorites. It is artificially formed as a by-product in blast furnaces, in the manufacture of soda, and of carborundum.

The method of its formation in nature has not yet been made out.

Graphite is used in the manufacture of pencils, as a lubricant, a paint pigment, and in the manufacture of crucibles and other refractory wares.

AIDS IN THE STUDY

OF

MINERALS

BY

C. W. ROLFE

ABBREVIATIONS

B. B.—Before the blowpipe.
Ch.—Charcoal.
D.—Difficulty fusible.
E.—Easily fusible.
I.—Infusible before the blowpipe.
M.—Medium fusibility.
O. F.—Oxidizing flame.
R. F.—Reducing flame.
S. Ph.—Salt of phosphorus or Microcosmic salt.

SPECIAL REACTIONS FOR THE ELEMENTS

I. Aluminum—Al.

1. Infusible minerals containing alumina, when oxidized B. B., moistened with cobalt solution, and strongly oxidized again, assume a fine blue color. If the substance is absorbent, a fragment will answer; but if non-absorbent, it must be powdered and treated on charcoal. Metallic oxides interfere with this reaction. (See Zn.)

2. (1) Decompose substance if necessary. (See Si, 3.)

(2) Dissolve in HCl, weaken acid with NH_4HO; filter if necessary.

(3) Treat thoroughly with H_2S. Filter if necessary.

(4) Add to filtrate NH_4Cl. Make alkaline with NH_4HO, and add a little $(NH_4)_2S$. Heat gently. Filter. Wash.

(5) Dissolve precipitate in HNO_3. Filter if necessary. Make alkaline with NaOH. Add Na_2O_2. Boil. Filter.

(6) Make filtrate acid with HCl. Add NH_4HO in excess. White precipitate=Al.

NOTE.—*Keep solutions concentrated.*

In the known absence of metals of group II, No. 3 may be omitted; and in the known absence of Fe, Mn, Co, and Ni, the dissolved precipitate under 5 may be treated at once with NH_4HO. White ppt=Al.

II. Ammonia NH_4OH.

Is recognized by mixing the substance with two parts dry soda or lime, and slowly heating in the closed tube. Ammonia vapors, recognizable by their odor, are given off.

III. Antimony—Sb.

1. Colors the flame bluish-green. (See P.)

2. On Ch. B. B., first in R. F. then in O. F., gives white fumes with no distinctive odor (See As), coating the coal white near the assay. (See As) This coating turns red after treating with HI in O F. and disappears on treatment with strong NH_4 HO. (See As, Bi, Pb.)

3. If a few drops of HCl solution of antimony be put in a platinum capsule with a small fragment of zinc, the inside of the capsule will be coated black.

4. If a substance containing antimony is mixed with sodium thio sulphate and heated in the closed tube, it becomes orange-red, and by further heating, black.

5. If presence of other substances interferes with the above reactions, boil the powdered mineral in strong HNO_3, dilute, filter and test powder.

IV. Arsenic—As.

1. Colors the flame bluish-white and gives off the odor of garlic.

2. On Ch. B. B. gives white fumes, garlic odor, and coat the coal white at a distance from the assay. (See Sb.) This coating turns orange or yellow on treatment with HI in O. F. (See Sb, Bi, Pb.)

3. In the closed tube with a fragment of charcoal above it, when slowly heated first above and then below assay, gives a black mirror of metallic arsenic. It is sometimes necessary (arsenates) to add to the assay four volumes of Na_2CO_3 with powdered charcoal, and heat intensely in O. F.

4. If a substance containing arsenic is mixed with sodium thio-sulphate and heated in a closed tube, it changes to a yellow color. (See Sb.)

V. Barium Ba.

1. Flame yellowish-green, either before or after moistening with HCl. (Compare B, P.)

2. Barium is precipitated from dilute acid solutions by H_2SO_4. This precipitate is insoluble in strong $(NH_4)_2SO_4$. Test precipitate under 3. (See Sr and Ca.)

3. Solutions containing barium give in the spectroscope several green bands between D and E or 50 and 70.

4. Insoluble silicates must be decomposed before the above tests are applied. (See Si.)

VI. Beryllium (Glucina)—Be.

1. Glucina gives a light grayish-blue color with Co $(NO_3)_2$ in O. F. (See Si, insoluble silicates.)

VII. Bismuth—Bi.

1. Bismuth minerals give a coating on Ch., orange while hot, yellow to white when cold. This treated with HI turns orange red. (See Sb, As, Pb.)

2. Compounds of bismuth, when powdered and mixed with three parts of a mixture of KI and S, and then treated on Ch. in O. F., give a bright orange to red and brown coating.

3. If a mixture of a bismuth mineral and Na_2CO_3 is treated in R. F. on Ch., a brittle globule of bismuth will be obtained. (See Pb.)

VIII. Boron—B. (Boric Acid—B_2O_3)

1. Boric acid colors the flame yellowish-green. In some cases it is necessary only to powder the mineral and moisten it with H_2SO_4. In others it is necessary to mix the powdered mineral with two parts of CaF_2 and three of $HKSO_4$ Make a thin paste of this with H_2SO_4, and introduce it into the flame by means of the platinum loop. The color is usually of but short duration. (See Ba, Ph.)

2. In alkaline solutions containing boric acid, $BaCl_2$ produces a white precipitate of $BaBO_4$ (See H_2SO_4.)

3. If turmeric paper is moistened in dilute HCl solution of a mineral containing Boron (if the mineral is insoluble it must first be decomposed, see Silicon) and dried at 150° or less, it will be colored reddish brown, and will turn black on treatment with NH_4HO.

IX. Bromine—Br.

1. When a bromide is fused in the closed tube with $HKSO_4$ and MnO_2, brown vapors of bromine are given off.

X. Cadmium—Cd.

1. Minerals containing cadmium, when mixed with Na_2CO_3 and heated in R. F. on Ch., give a brown coating, which, on being moistened with H_2SO_4 and heated, turns white. See Zn. (The Cd. coating appears at a lower temperature than that of Zn.)

2. Cadmium minerals, when mixed with sodium thio-sul-

phate in a closed tube and heated, give a cinnabar-red while hot and yellow when cold. (See Sb, As.)

3. In solutions of cadmiferous minerals, H_2S gives a yellow precipitate.

XI. Cæsium—Cs.

1. Colors the flame violet.

2. Gives in spectroscope two blue bands midway between F and G, 105–110.

XII. Calcium—Ca.

1. Calcium oxide colors the flame orange-red. Sometimes it is necessary to moisten the mineral with HCl or H_2SO_4 (See Sr.)

2. In the spectroscope, calcium gives a green band midway between D and E, or 58-63, an orange band between C and D, or 40-45 and a blue one one just beyond G, or 135.

3. In the absence of barium and strontium, powder the mineral and treat in O. F. on Ch. Then moisten with a drop of chromic acid and heat again. If Ca is present the assay assumes a fine green color.

4. In alkaline solutions of substances containing calcium, ammonium oxalate produces a white precipitate. Ba and Sr are also precipitated by this reagent. Test precipitate in spectroscope.

5. Concentrated solutions give precipitates with *but little* H_2SO_4, which dissolve on addition of water and boiling, or on addition of $(NH_4)_2SO_4$ (See Ba and Sr.)

6. Insoluble silicates must in many cases be decomposed before the above tests are applied. (See Si.)

XIII. Carbon—C.

1. Graphite and anthracite detonate when fused with nitre in a platinum dish, and afterward effervesce with HCl.

2. Hydro-carbon compounds burn with a yellow flame.

3. If carbonaceous substances are strongly heated in a bulb tube which has been drawn out, the escaping gas will burn at the opening.

XIV. Carbonic Acid—CO_2.

1. The presence of this acid is indicated by effervescence with either hot or cold acids.

XV. Cerium.—Ce.

1. Substances containing cerium, give to the borax bead in the O. F. a reddish color while hot, and yellow when cold. If saturated, this becomes yellow and enamel-like. A saturated bead in R. F. becomes crystalline when cold.

2. Cerium can be detected by precipitating with ammonia, filtering, washing, and treating the residue with oxalic acid. This, after washing, is then ignited, and assumes a brick-red or cinnamon-brown color.

XVI. Chlorine—Cl.

1. A S. Ph. bead, saturated with CuO, gives the O. F. a yellow color. If a mineral containing chlorine is introduced into the bead, the O. F. becomes azure-blue.

2. In solutions containing chlorine, $AgNO_3$ produces white precipitates of AgCl.

NOTE.—Br and I produce similar reactions.

XVII. Cromium—Cr.

1. Chrome minerals give emerald-green beads in R. F. In the O. F. borax beads are red to yellow while hot, yellow to yellowish green when cold. Salt of phosphorus beads are green, both hot and cold. (See Vanadium.)

2. If chrome compounds are mixed with soda and nitre, and fused on platinum foil, yellow sodium chromate is produced.

XVIII. Cobalt—Co.

1. Cobalt minerals are magnetic after fusion.

2. Cobalt oxide gives a fine blue color to beads in both flames.

3. If Ni or Fe interferes with the reaction, fuse the bead on charcoal with a granule of tin in the reducing flame until the bases are reduced. The flux will then be blue. (See Cu.)

XIX. Columbium—Cb.

1. If a S. Ph. bead, saturated with a mineral containing columbic acid, is powdered and boiled in strong HCl, with metallic zinc, a fine blue color will be produced.

XX. Copper—Cu.

1. Copper oxide colors the flame emerald-green; but if the mineral is moistened with HCl, the color is changed to azure-blue. Sulphides should be roasted or fused before treating with acid.

2. Copper compounds give to beads in the O. F. a green color while hot, and a blue color when cold. In the R. F. the color becomes sealing-wax red. (See Co)

3. Acid solutions of copper become blue with excess of ammonia. (See Ni.)

4. Clean iron dipped into an acid solution of copper becomes plated.

XXI. **Didymium—Di.**

1. The borax bead is pink in R. F.

XXII. **Fluorine—F.**

1. Mix the powdered mineral with some S. Ph., and put in an open tube, about half an inch from the end. Heat strongly. Upon breaking the tube it will be found to be etched.

2. Sometimes it is only necessary to mix the powdered mineral with H_2SO_4, or $HKSO_4$, on a piece of glass. The polish will be removed.

3. To the finely powdered mineral add an equal amount of fine sand. Make into a thick paste with conc. H_2SO_4 in test tube. Warm gently until white fumes are freely given off. Introduce into the tube a glass rod carrying a drop of water. If F. is present the drop will be covered with a white film of SiF_4.

XXIII. **Gold—Au.**

1. Compounds of gold are reduced on Ch , and by powdering in a mortar with water, yellow particles of gold may be obtained.

2. $FeSO_4$ precipitates gold as a brown powder.

3. Stannous chloride produces, in solutions of gold, a purple-red precipitate, the "Purple of Cassius."

XXIV. **Indium—In.**

1. Indium colors the flame intensely blue-violet.

2. On Ch. a yellow coating is formed.

3. The spectroscope shows a blue band midway between F and G, and another about midway between G and H

XXV. **Iodine—I.**

1. Iodine compounds, when fused with $HKSO_4$ give off violet vapors.

XXVI. **Iron—Fe.**

1. Some iron compounds are magnetic, others become so after fusion or ignition, while still others give magnetic powders after fusion with soda.

2. Borax beads of iron are red to yellow while hot, colorless to yellow when cold in the O. F. In the R. F. they become bottle-green.

3. If a borax bead containing iron is oxidized, powdered and dissolved in a few drops of HCl, and then a few drops of HNO_3 added, a small crystal of K_4FeCN_6 will produce a bright blue color. NH_4CNS produces in the HCl solution a deep blood-red color.

XXVII. **Lead—Pb.**

1. Lead compounds color the flame pale azure-blue (see Sb, As, Cu.), and in R. F. on Ch. give a yellow coating.

2. Metallic lead is obtained sometimes without a flux, but in other cases it is necessary to fuse with soda on Ch. in R. F. The globule is malleable. (See Bi.)

3. Lead compounds mixed with three parts of KI and S, and fused on Ch. in O. F., give a yellow coating fringed with bright green. (See Sb, Bi, As.)

4. Solutions of lead give white precipitates with HCl and H_2SO_4. (See Ag and Hg.)

XXVIII. **Lithium—Li.**

1. Lithia colors the flame carmine.

2. The spectroscope shows a bright red band between B and C, or 32.

XXIX. **Magnesium—Mg.**

1. Decompose substance if necessary. (See Si 3.)

2. Dissolve in HCl. Weaken acid with NH_4HO. Filter if necessary.

3. Treat thoroughly with H_2S. Filter if necessary.

4. Add to filtrate NH_4Cl. Make alkaline with NH_4HO, and add a little $(NH_4)_2S$. Filter if necessary.

5 Boil filtrate thoroughly. Filter until clear. Boil. Add NH_4Cl and $(NH_4)_2CO_3$. Filter if necessary.

6. Add NH_4HO and S. Ph. to filtrate. Boil. A white precipitate = Mg.

NOTE.—*During the operation the solution should be kept concentrated.*

In the known absence of metals of Group II, No. 3 may be omitted.

XXX. **Manganese—Mn.**

1. All manganese minerals give beads that are amethystine-red in O. F., and colorless in R. F.

2. Beads made of a mixture of two parts of soda and one of nitre, give a blue-green (turquois) color with manganese minerals.

XXXI. **Mercury—Hg.**

1. When minerals containing mercury are heated in a closed tube with three parts of dry soda, globules of mercury accumulate on the sides of the tube.

2. A drop of neutral or feebly acid solution of mercury placed on clean copper, then washed and rubbed with paper, produces a silver-like plating.

3. Salts of mercury are precipitated by HCl. (See Pb and Ag).

XXXII. **Molybdenum—Mo.**

1. On Ch., molybdenum minerals give a coating that is yellow while hot and white when cold. This passed through a weak R. F., changes to blue.

2. A blue color is produced with minerals containing molybdenum by heating the finely powdered mineral in a porcelain dish with conc. H_2SO_4 and then pouring some alcohol in the dish after it has cooled.

3. Molybdic acid heated upon platinum foil with conc. H_2SO_4 until it fumes strongly, and then breathed upon, turns blue.

4. Mo. salts color S. Ph. beads green, in R. F.

XXXIII. **Nickel—Ni.**

1. Oxidized Nickel beads are brown when cold. In R. F. long continued, a gray film of metallic nickel is formed.

2. Many nickel minerals become magnetic after fusion, and all of them yield a magnetic powder when reduced with soda. This fact makes possible the separation of the nickel by pulverizing in a mortar with water, and picking out the magnetic particles with a magnet. These may then be further tested.

3. Acid solutions of nickel are apple-green. Ammonia produces a greenish precipitate, which is dissolved in an excess of the reagent, and the solution becomes blue.

XXXIV. **Nitrogen—N.** (**Nitric Acid HNO_3**).

1. Nitrates detonate on charcoal and deflagate upon ignition.

2. When nitrates are heated in a closed tube with $HKSO_4$ reddish brown fumes are given off.

XXXV. **Osmium—Os.**

1. On Ch. and in the open tube, osmium yields a characteristic odor somewhat like chlorine, but does not give the other reactions for chlorine.

XXXVI. **Phosphorus—P.** (**Phosphoric Acid—P_2O_5.**)

1. Phosphoric acid colors the flame bluish-green. (See Sb, Ba.)

2. In an arsenical tube, or in an ordinary tube drawn out and closed, put a mixture of the mineral with soda and charcoal. Then thrust into this mixture, so that it is completely covered, a small piece of magnesium ribbon. Heat B. B. until the glass and mixture are fused. Break off the end of the tube, crush it and pour water over it. The odor of phosphuretted hydrogen (decaying fish) will be given off.

3. Acid or neutral solutions of phosphates give a pulverulent yellow precipitate with ammonium molydate solution. The reaction may be hastened by *gently* warming. Do not boil.

XXXVII. **Platinum—Pt.**

1. Soluble only in aqua regia.

2 H_2S throws down a blackish-brown precipitate of PtS_2 after some time. This may be hastened by warming.

XXXVIII. **Potassium—K.**

1. Salts of potassium color the flame violet. If the color is obscured by sodium, this may be obliterated by cobalt glasses. The potassium flame then appears purple. (See Pb.)

2. Potassium is precipitated, if not too dilute, by platinic chloride, as a yellow crystalline precipitate.

3. The spectroscope gives a red band at A or 17 and a blue one beyond G or 153.

XXXIX. **Rubidium—Rb.**

1. Compounds of rubidium color the flame violet. (See K.)

2. The spectroscope gives two red bands beyond A, or 15, and two blue ones beyond G, or 135.

XL. Selenium—Se.

1. Volatilizes, giving off red fumes, and emiting the odor of decaying horse-radish.

2. On Ch., gives a metallic gray coating near assay, and reddish-brown further off.

3. Metallic copper, when plated in a warm solution of selenious acid containing HCl, becomes coated black immediately. If it remains in the solution for any length of time it becomes light red.

XLI. Silicon—Si. (Silicic Acid—SiO_2)

1. Most silicates show the presence of silica by leaving a skeleton in S. Ph. bead, when a small fragment is introduced into the bead and treated in the O. F. The bases are dissolved, while the silica remains floating in the bead, and retains somewhat its original form. This is not very reliable.

2. The silica in some silicates, gelatinizes with HCl. The mineral is finely powdered and covered with acid in a test tube. This is heated slowly, and as the acid evaporates, the residue forms a jelly. In some cases the silica does not form a stiff jelly. Some gelatinize only after fusion or ignition. To test for bases, add some more acid, evaporate to dryness, dissolve in HCl and filter out the silica.

3. To decompose insoluble silicates, so that the bases may be determined:

    1. Powder finely. To a quantity of the powder half the size of a pea or larger, add two parts of $Na_2B_4O_7$ or $(NH_4)_2HPO_4$, or Na_2CO_3 or $Na_2CO_3 + K_2CO_3$.* Mix. Moisten mixture with water. Place on a flat coil of wire and fuse strongly.
    2. Powder the bead finely. Dissolve in strong HNO_3 Add a granule of Sn. and boil thoroughly. Filter.
    3. Evaporate to dryness. Continue heating carefully until water of crystallization is driven off.
    4. Dissolve in HCl. Precipitate=silica.
    5. Filter. Test filtrate for bases.

---

*For dry or B. B. tests, silicates may be decomposed with $KHSO_4$, or CaF_2, or BaF_2, or HF.

XLII **Silver—Ag.**

1. When silver is fused on Ch., it gives a brown-red coating near the assay.

2. Metallic silver is obtained by mixing the compound with three parts soda and treating on Ch. in R. F.

3. In solutions of silver in nitric acid, HCl produces a white precipitate of AgCl, insoluble in water, but soluble in NH_4OH. If lead is present, it may first be precipitated with H_2SO_4, or both lead and silver precipitated with HCl, and the silver dissolved again by NH_4OH, and again precipitated with HCl. (See Pb and Hg.)

XLIII. **Sodium—Na.**

1. Colors the flame an intense yellow, which is obliterated by cobalt glasses.

2. Gives a single yellow band in the spectroscope at D, or 50.

XLIV. **Strontium—Sr.**

1. Colors the flame vermilion-red.

2. In the spectroscope strontium shows several red bands between B an dC or 28-37, an orange between C and D, or 37-48, and a blue one between F and G, or 105.

3. In dilute solutions, strontium is precipitated as a white powder by H_2SO_4, which does not dissolve on diluting and boiling, or on addition of strong $(NH_4)_2SO_4$ Test precip. under 2. (See Ca and Ba.)

XLV. **Sulphur—S.**

a. Native sulphur—

1. If native sulphur, sulphides, or sulphates are powdered, mixed with soda and treated on Ch. B. B., the first two in O. F. first, and then in R. F., the latter in R. F. entirely, the fused mass, when powdered, put on bright silver and moistened, will stain the silver black.

2. Native sulphur burns with a bluish flame, giving the odor of SO_2.

b. Hydrosulphuric Acid—H_2S.

1. Sulphides dissolved in HCl or H_2SO_4 give off hydrosulphuric acid.

2. Sulphides, when dissolved in HNO_3, or aqua regia, liberate free sulphur.

3. Sulphides finely powdered and heated in an open tube give off fumes of SO_2.

c. Sulphuric Acid—H_2SO_4.

1. Solutions of sulphates give precipitates with $BaCl_2$

XLVI. **Tellurium—Te.**

1. Colors the flame bluish and coats the coal white. This coating, when moistened with conc. H_2SO_4 and gently heated, becomes cherry-red.

2. Tellurides, finely powdered and treated with conc. H_2SO_4, give reddish-violet solution.

XLVII. **Thallium—Tl.**

1. Colors the flame brilliant green, and gives a brown-red coating on Ch.

2. The finely powdered mineral, mixed with KI and S and treated in the O. F., produces a bright greenish-yellow coating, fringed with green. (See Pb and Bi.)

3. The spectroscope shows a bright green band near E, or 70.

XLVIII. **Tin—Sn.**

1. Tin oxide coats the coal a faint yellow while hot, white when cold. This moistened with cobalt solution, gives a greenish-blue color in a weak O. F. It is best obtained after fusion with soda.

2. Metallic tin may be obtained by fusion with soda and borax in R. F. If the fused mass, together with the charcoal immediately under and around it, is powdered in an agate mortar under water, and the charcoal poured off, flat particles of metallic tin may be seen.

XLIX. **Titanium—Ti.**

1. Colors the S. Ph. bead violet-blue in the R. F.

2. If a mineral containing TiO_2 is fused with soda and borax, and then dissolved in HCl, the solution turns pink upon the addition of metallic zinc and evaporating.

L. **Tungsten—W.**

1. Tungstates, fused with soda and nitre and then dissolved in HCl, give a fine blue color upon the addition of metallic zinc.

LI. **Uranium U.**

1. In S. Ph., uranium minerals give beads that are yellow while hot, yellow-green when cold, and in R. F. pure green. By flaming they become black.

LII. **Vanadium—V.**

1. Vanadates containing no metallic oxides, give with salt of phosphorous in the O. F. yellow to deep amber beads. In R. F. the beads are dirty green while hot, and emerald-green when cold. S. Ph. beads in R. F. give identical reactions with V. and Cr. (See Chromium.)

2. If vanadates are fused with KNO_3, dissolved in H_2SO_4, diluted and metallic zinc added, the solution first appears blue, then green, and finally violet.

LIII. **Yttrium—Yt.**

1. HF produces precipitate of yttrium fluoride.

LIV. **Zinc—Zn.**

1. The *finely powdered* mineral mixed with one part Na_2CO_3 and charcoal, moistened and heated in *reducing flame* on charcoal, colors the flame greenish white, and coats the coal yellow while hot, white when cold. The coat strongly oxidized, moistened with cobalt solution and oxidized again gives a green color. The coating is best produced by fusing with soda.

2. Silicates of Zn, if infusible, when oxidized, moistened with $CoNO_3$ and strongly heated again give a fine blue. (See Al.)

LV. **Zirconium—Zr.**

1. Zirconium salts are precipitated by sodium and ammonium carbonates, as a white flocculent precipitate.

2. Dilute hydrochloric acid solutions of Zirconium change turmeric paper orange-yellow after drying. This should always be checked by wetting a piece of the same paper in acidulated water of the same strength and drying.

TABLE FOR THE DETERMINATION OF MINERALS.

INTRODUCTION.

This table is intended to aid the student in the rapid determination of species. The results arrived at by its use, while probably correct, should never be accepted without verification by means of chemical tests for bases and acids.

The table is designed for use in connection with Dana's Text-Book of Mineralogy where other physical properties, together with the chemical composition, usual associations, common alterations, differences between the given mineral and others which might be mistaken for it, etc,, are given.

All these should be taken into consideration, and as many of them verified as circumstances will permit, before the determination is regarded as certain.

The properties given in the tables are those possessed by minerals having the ideal chemical composition and molecular aggregation, hence, as these are constantly varying, some latitude must be allowed.

The student should remember that finding the name of a mineral is only a necessary incident in its study A thorough acquaintance with its origin variations, associations, and usual decomposition products is the point aimed at.

GENERAL CLASSIFICATION.

I—MALLEABLE MINERALS,

REMARKS.	CLEAVAGE OR FRACTURE.	CRYSTAL SYSTEM.	COMPOSITION.
Copper is used in making wire and engravers' plates; for electrical purposes, in making alloys and pigments.	F. conchoidal.	Iso.	$Ag_2 S$.
	F. hackly.	Iso.	Ag.
Native copper often occurs as the result of decomposition of copper sulphide, and is often accompanied by malachite and azurite, as a result of its own decomposition.	F. hackly.	Iso.	Au.
	F. hackly.	Iso.	Cu.
Gold occurs in arborescent forms, threads, or massive, and is usually associated with quartz or pyrite.	F. hackly. [rections	Iso.	Pt.
	F. hackly. C. in 2 di-	Iso.	Pd, Pt, Ir.
	F. hackly.	Iso.	Fe, Ni.
Iridium is used for hardening steel, for pen points, and for producing a dead black color in the manufacture of porcelain.	F. hackly.	Iso.	Ir, Os, Rh, Pt.
			Hg.

II.—SECTILE MINERALS,

REMARKS.	CLEAVAGE OR FRACTURE.	CRYSTAL SYSTEM.	COMPOSITION.
Antimony expands in cooling, and consequently enters into the composition of type metal and other alloys which are intended to take sharp impressions from molds. It is also used in making anti-friction alloys, babbit metal, and in medicine.	C. basal. F. brittle.	Hex.	Bi.
	C. cubic.	Iso.	Pb, Te.
	F. granular, brittle.	Hex.	As.
	C. basal.	Ortho.	Ag S. Sb.
	C. basal.	Hex.	$Mo\ S_2$.
	C. pinacoidal.	Ortho.	$Au_2\ Pb_{14}\ Sb_3\ Te_7\ S_{17}$.
	C. pinacoidal.	Monoc.	$(Au\ Ag)\ Te_2$.
	C. basal.	Hex.	Bi Te. $Bi_6\ Te_4\ S_6$.
	C. pinacoidal.	Ortho.	$Sb_2\ S_3$.
Molybdenite, an ore of molybdenum used principally in chemical manufactures; and in dyeing. It is often mistaken for graphite.	C. pinacoidal.	Ortho.	$Bi_2\ S_3$.
	F. conchoidal.	Iso.	$Ag_2\ S$.
	F. uneven.	Iso.	$Ag_2\ Te$.
	F. uneven.	Ortho.	$Pb\ Sb_2\ S_4$.
	C. cubic.	Iso.	Mn S.
Graphite. See note, p. 3.	C. pinacoidal.	Ortho.	$Au_2\ Pb_{14}\ Sb_3\ Te_7\ S_{17}$.
	C. basal.	Hex.	C.
Arsenic. See Arsenopyrite, p. 5.	C. basal.	Hex.	Cu S.
	F. uneven.	Ortho.	$Ag_2\ S$.
	F. conchoidal.	Iso.	Hg Se.
Bismuth. See note, p. 4.	F. pinacoidal.	Ortho.	$Cu\ Bi\ S_2$.
	F. uneven.	Ortho.	Cu Ag S.
	F. uneven.	Ortho.	$Cu_2\ S$.
	F. conchoidal.	Ortho.	$3\ Cu_2\ S.\ 2\ Bi_2\ S_3$.

NAME.	PAGE IN DANA.	HARDNESS.	GRAVITY.	STREAK.	COLOR.
1. FUSIBILITY EASY.					
Argentite	288	2 - 2.5	7.2- 7.4	lead gray.	black.
Silver	278	2.5- 3	10 -11	silver white	silver white.
Gold	275	2.5- 3	15.6-19.5	yellow.	yellow.
2. FUSIBILITY MEDIUM.					
Copper	278	2.5- 3	8.8- 9	red.	red.
3. INFUSIBLE.					
Platinum	280	4 - 4.5	14 -19	light gray.	light gray.
Palladium	281	4.5- 5	11.3-11.8	white.	white.
Iron	281	4.7- 5	7.3- 7.8	gray.	gray.
Iridosmine	280	6 - 7	19 -21	gray.	tin white.
4. LIQUID.					
Mercury	279		13.5		white.

METALLIC LUSTRE.

NAME.	PAGE IN DANA.	HARDNESS.	GRAVITY.	FUSIBILITY.	COLOR.
1. STREAK WHITE.					
Bismuth	275	2 - 2.5	9.7- 9.8	E.-Vol.	white.
Altaite	288	3 - 3.5	8.15	E.	white.
Arsenic	274	3.5-	5.6- 5.7	Vol.	white.
Dyscrasite	286	3.5- 4	9.4- 9.8	E.	white.
2. STREAK GRAY.					
Molybdenite	285	1 - 1.5	4.4- 4.8	I.	gray.
Nagyagite	305	1 - 1.5	6.8- 7.2	E.	black to gray.
Sylvanite	304	1.5- 2	8 - 8.3	E.	white to gray.
Tetradymite	284	1.5- 2	7.2- 7.6	E.	gray.
Stibnite	283	2	4.5- 4.6	E.	gray.
Bismuthinite	284	2	6.4- 7.2	E.	gray.
Argentite	288	2 - 2.5	7.2- 7.4	E.	black.
Hessite	289	2 - 3.5	8.3- 8.6	E.	gray.
Zinkenite	307	3 - 3.5	5.3- 5.4	E.	gray.
3. STREAK GREEN.					
Alabandite	292	3.5- 4	3.9- 4	M.	black.
4. STREAK BLACK.					
Nagyagite	305	1 - 1.5	6.8- 7.2	E.	black to gray.
Graphite	273	1 - 2	2 - 2.2	I.	black.
Covellite	294	1.5- 2	4.5- 4.6	E.	blue.
Acanthite	290	2 - 2.5	7.1- 7.3	E.	black.
Tiemannite	292	2.5	7.1- 8.5	Vol.	lead gray.
Emplectite	308	2.5	6.3- 6.5	E.	white to gray.
Stromeyerite	290	2.5- 3	6.1- 6.3	E.	black to gray.
Chalcocite	290	2.5- 3	5.5- 5.8	E.	black.
Wittichenite	310	2.7- 3.5	4.3- 5	E.	lead gray to black.

REMARKS.	CLEAVAGE OR FRACTURE.	CRYSTAL SYSTEM.	COMPOSITION.
See note on brucite, p. 3.	F. conchoidal.	Tet.	$Hg\ Cl.$
	F. uneven.	Iso.	$As_2\ O_3.$
Sulphur. See note, p. 13.	F. conchoidal.	Iso.	$NH_4\ Cl.$
Gypsum is used as a source of plaster-of-paris; as a fertilizer; in mortar; and in the manufacture of artificial stone. It varies widely in structure and color, from the beautiful, almost precious satin spar to an earthy mass like kaolin.	C. basal.	Tri.	$B\ (OH)_3.$
	F. uneven.	Iso.	$Ag\ (Cl\ Br).$
	F. uneven.	Iso.	$Ag\ Cl.$
	C. 3 directions.	Mono.	$Ca\ SO_4.\ \ 2\ H_2O.$
Pinite is always secondary. It is formed by the alteration of widely different minerals.	C. pinacoidal.	Mono.	$Fe_3\ (PO_4)_{21}.\ \ 8\ H_2O.$
	F. uneven.	Iso.	$Ag\ Br.$
			$H_6\ K_2\ Al_2\ Si_5\ O_{20}.$
As beauxite is an impure oxide of aluminum, it varies in structure and color with the character and amount of its impurities. Pure beauxite would be white. It is the principal ore of aluminum at present.	C. basal.		$H_2\ Mg_3\ (SiO_3)_4.$
	C. basal.		$H_2\ Al_2\ (SiO_3)_4.$
	F. uneven.		$H_4\ Mg_2\ Si_3\ O_{10}.$
	F. uneven.		$H_4\ (Mg\ Fe)_3\ Si_2\ O_9.$
	C. basal.	Mono.	$H_4\ Al_2\ Si_2\ O_9.$
Talc and kaolin are very similar in properties, and are often indistinguishable except by chemical tests. The variety of talc called meerschaum or sepiolite is often used in place of china clay.	C. basal.		$H_2\ Mg_3\ (SiO_3)_4.$
	F. uneven.		$Cu\ SiO_3.\ \ 2\ H_2O.$
	C. pinacoidal.	Mono.	$Fe_2\ (Fe\ OH)_2\ (S\ O_4)_5.\ \ 17\ H_2O.$
	C. basal.	Hex.	$Mg\ (OH)_2.$
	F. conchoidal.		$H_6\ Fe_2\ (SiO_4)_3.\ \ 2\ H_2O.$
	F. uneven.		$H_4\ Ni_2\ Mg_2\ (SiO_4)_3.\ \ 4\ H_2O.$
			$Al_2\ O,\ (OH)_4.$
Note the relationship between serpentine and talc: both are formed by alteration of the same minerals.	F. conchoidal.	Ortho.	$S.$
	C. basal.	Hex.	$Ag\ I.$
Serpentine is much used for interior decoration, under the names of green and red marble. The pure, almost transparent, green varieties are also used as precious stones.	C. pinacoidal.	Mono.	$As_2\ S_3.$
			$Pb\ O.$
	F. uneven.	Mono.	$Pb\ CrO_4.$
	F. uneven.	Iso.	$Ag\ (Cl\ Br).$
	C. prismatic.	Hex.	$Hg\ S.$
Cinnabar is usually impure from the admixture of gangue, and rarely shows a specific gravity so high as that given, for this reason. Vermilion paint pigments are made from it.	C. pinacoidal.	Mono.	$Sb_2\ S_2\ O.$
	C. pinacoidal.	Mono.	$As\ S.$
	C. pinacoidal.	Mono.	$Co_3\ (AsO_4)_2.\ \ 8\ H_2O.$
	C. pinacoidal.	Mono.	$3\ Ag_2\ S.\ \ Sb_2\ S_3.$
	F. uneven.	Mono.	$Ag_2\ S.\ \ Sb_2\ S_3.$
	F. conchoidal.	Hex.	$3\ Ag_2\ S.\ \ Sb_2\ S_3.$
Realgar and orpiment usually occur together. Much of the commercial supply is artificial.	F. conchoidal.	Hex.	$3\ Ag_2\ S.\ \ As_2\ S_3.$
	C. basal.	Hex.	$Cu\ S.$
	C. pinacoidal.	Mono.	$Fe_3\ (PO_4)_2.\ \ 8\ H_2O.$

NAME.	PAGE IN DANA.	HARDNESS.	GRAVITY.	LUSTRE.	COLOR.
1. STREAK WHITE.					
(a) Volatile.					
Calomel	317	1 - 2	6.5	adamantine,	white, variable.
Arsenolite	330	1.5	3.7	vitreous, silky, adamantine.	white.
Sal Ammoniac	319	1.5- 2	1.5	greasy vitreous.	white.
(b) Easily Fusible.					
Sassolite	352	1	1.5	pearly.	white.
Embolite	319	1 - 3	5.3- 5.8	adamantine.	gray, green or yellow.
Cerargyrite	319	1 - 3	5 - 6	resinous, adamantine.	gray, variable.
Gypsum	531	1.5- 2	2.3	vitreous, pearly.	white, variable.
Alabaster, a fine grained massive variety. Satin Spar, a fibrous variety, opalescent lustre.					
Vivianite	508	1.5- 2	2.5- 2.7	pearly, vitreous.	white, variable.
Bromyrite	319	1.5- 3	5.8- 6	adamantine.	yellow, variable.
Pinite	466	2.5- 3.5	2.6- 2.8	waxy.	green, variable.
(c) Difficultly Fusible.					
Talc	479	1 - 1.5	2.5- 2.8	pearly, adamantine.	white, variable.
Pyrophyllite	482	1 - 2	2.7- 2.9	pearly.	white, variable.
Sepiolite	480	2 - 2.5	1 - 2	earthy.	white, variable.
°Serpentine	476	2.5- 5.5	2.2- 2.6	var.	green, variable.
(d) Infusible.					
Kaolinite	481	1 - 2.5	2.4- 2.6	pearly, adamantine.	white, variable.
Talc	479	1 - 1.5	2.5- 2.8	pearly, adamantine.	white, variable.
°Chrysocolla	483	2 - 4	2 - 2.2	vitreous.	blue to green
Copiapite	536	2.5	2.1	pearly.	yellow. var.
Brucite	351	2.5	2.3- 2.4	pearly, vitreous.	white, variable.
Chloropal	484	2.5- 4.5	1.7- 1.8	resinous, waxy.	greenish.
*Genthite	479	3 - 4	2.4	resinous.	green to yellow.
Beauxite	350	3 ?	2.5	earthy.	white to brown.
2. STREAK YELLOW.					
(a) Volatile.					
Sulphur	274	1.5- 2.5	2 - 2.1	resinous.	yellow, brown.
(b) Easily Fusible.					
Iodyrite	319	1 - 1.5	5.5- 5.7	resinous, adamantine.	yellow, variable.
Orpiment	282	1.5- 2	3.4- 3.5	pearly, resinous.	yellow.
Massicot	332		7.8- 9.3	dull.	yellow.
Crocoite	529	2.5- 3	5.9- 6.1	vitreous, adamantine.	red.
3. STREAK GREEN.					
Embolite	319	1 - 3	5.3- 5.8	adamantine.	green, gray to yellow.
4. STREAK RED.					
(a) Volatile.					
Cinnabar	293	2 - 2.5	8 - 8.2	adamantine.	red.
(b) Easily Fusible.					
Kermesite	305	1 - 1.5	4.5- 4.6	adamantine.	red.
Realgar	282	1.5- 2	3.4- 3.6	resinous.	red, yellow.
Erythrite	509	1.5- 2.5	2.9	pearly, vitreous.	peach red.
Pyrostilpnite	312	2	4.2	pearly, adamantine.	red.
Miargyrite	308	2 - 2.5	5 - 5.4	adamantine.	black.
Pyrargyrite	311	2 - 2.5	5.7- 5.9	adamantine.	black to red.
Proustite	312	2 - 2.5	5.4- 5.6	adamantine.	red.
5. STREAK BLACK.					
Covellite	294	1.5- 2	4.5- 4.6	adamantine.	blue, black.
6. STREAK BLUE.					
Vivianite	508	1.5- 2	2.5- 2.7	pearly, vitreous.	white, variable.

*Garnierite, an impure earthy variety.
°Sometimes used as a gem stone.

THIN LAMINÆ, FLEXIBLE,

REMARKS.	CLEAVAGE OR FRACTURE.	CRYSTAL SYSTEM.	COMPOSITION.
Graphite is used in the manufacture of crucibles, pencils, lubricants and paints. It is probably always produced by the decomposition of carbonated gases through contact with highly heated substances, or by the action of heat on masses of organic matter. It is manufactured commercially by heating carbon in the electric arc.	C. basal.	Ortho.	$Ag\ Fe_2\ S_3$.
	C. pinacoidal.	Ortho.	$Au_2\ Pb_{14}\ Sb_3\ Te_7\ S_{17}$.
	C. basal.	Hex.	$Bi_2\ Te_3$.
	C. pinacoidal.	Ortho.	$Bi_2\ S_3$.
	C. basal.	Hex.	$Mo\ S_2$.
	C. basal.	Hex.	C.

NON-METALLIC

THIN LAMINÆ

REMARKS.	CLEAVAGE OR FRACTURE.	CRYSTAL SYSTEM.	COMPOSITION.
The micas occur both as primary and secondary minerals. The light-colored micas of commerce are almost exclusively derived from the alteration of feldspars. The dark micas, principally used (as are the trimmings and small plates of the light ones) for lubricants and paint pigments, are produced by the alteration of magnesian minerals. Because of widely varying composition the micas also vary widely in color, and cannot be separated on that basis alone. They also unite chemically with water, and become hydromicas.	C. pinacoidal.	Ortho.	$(K, Na\ H)_4\ (Fe\ Mn\ Mg\ Ca)_4\ Ti\ (SiO_4)_4$.
	C. basal.	Mono.	$(Li\ K\ [Al\ (OH\ F)_2]\ Al\ (Si\ O_3)_3$.
	C. basal.	Mono.	$(K\ H)_2\ Fe_2\ (Fe\ Al)_2\ (SiO_4)_3$.
	C. basal.	Mono.	$H_2\ K\ Al_3\ (SiO_4)_3$.
	C. basal.	Mono.	$(K\ H)_2\ (Mg\ Fe)_2\ (Al\ Fe_2)_2 (SiO_4)_3$.
	C. basal.	Mono.	$(H\ K)_3\ (Mg\ Fe)_3\ (Al\ Fe)\ (SiO_4)_3$.

THIN LAMINÆ FLEXIBLE,

The micas decompose into hydromicas, then into talc or kaolin, according as magnesia or alumina is the more prominent base.	C. pinacoidal.	Mono.	$As_2\ S_3$.
	C. foliated.		$H_6\ (Fe\ Mg)_2\ (Fe\ Al)_2\ Si_5\ O_{18}$.
	C. basal.		$H_2\ Mg_3\ (SiO_3)_4$.
	C. basal.		$H_2\ Al_2\ (SiO_3)_4$.
	C. basal.	Mono.	$H_{40}\ (Fe\ Mg)_{23}\ Al_{14}\ Si_{13}\ O_{90}$.
See note on talc and kaolin, p. 2.	C. basal.	Mono.	$Mg\ Al\ Si\ O_2.\ H_2O$?
See note on realgar and orpiment.	C. basal.	Mono.	$H_8\ Mg_5\ Al_2\ Si_3\ O_{18}$.
	C. basal.		$H_8\ {}^*R_2\ Al_4\ Si_9\ O_{36}$.
	C. basal.	Mono.	$H_2\ Ca\ Al_4\ Si_2\ O_{12}$.
Brucite can be distinguished from talc, which it closely resembles, by its solubility in acids and by a slight alkaline reaction after ignition.	C. basal.	Mono.	$H_2\ Fe\ Al_2\ SiO_7$.
	C. basal.	Mono.	$H_4\ Al_2\ Si_2\ O_9$.
	C. basal.	Hex.	$Mg\ (OH)_2$.
	C. basal.	Mono.	$H_2\ Na\ Al_3\ (SiO_4)_3$.
	C. basal.	Mono.	$H_3\ (Mg\ Ca)_5\ Al_5\ Si_2\ O_{18}$.

*R. Stands for various bases.

BUT NOT ELASTIC.

NAME.	PAGE IN DANA.	HARDNESS.	GRAVITY.	STREAK.	COLOR.
1. FUSIBILITY EASY.					
Sternbergite	290	1 - 1.5	4.2	black.	pinchbeck [brown.
Nagyagite	305	1 - 1.5	6.8- 7.2	gray.	gray, black.
Tetradymite	284	1.5- 2	7.2- 7.6	gray.	gray.
Bismuthinite	284	2	6.4- 7.2	gray.	gray.
2. INFUSIBLE.					
Molybdenite	285	1 - 1.5	4.4- 4.8	gray.	gray.
Graphite	273	1 - 2	2 - 2.2	black.	black.

LUSTRE.

ELASTIC.

NAME.	PAGE IN DANA.	HARDNESS.	GRAVITY.	LUSTRE.	COLOR.
1. EASILY FUSIBLE.					
Astrophyllite	487	2	3.3- 3.4	submetallic, [pearly	bronze yellow.
°Lepidolite	467	2.5- 4	2.8- 3	pearly.	rose red to [white, var.
Lepidomelane	470	3	3 - 3.2	adamantine, [pearly.	black.
2. FUSIBILITY DIFFICULT.					
Muscovite	464	2 - 2.5	2.7- 3.1	pearly, vitreous.	white, var.
Biotite	467	2.5- 3	2.7- 3.1	pearly, sub- [metallic.	green to black.
Phlogopite	469	2.5- 3	2.7- 2.8	pearly, sub- [metallic.	brownish, red to [white.

BUT NOT ELASTIC.

NAME.	PAGE IN DANA.	HARDNESS.	GRAVITY.	LUSTRE.	COLOR.
1. FUSIBILITY EASY.					
Orpiment	282	1.5- 2	3.4- 3.5	pearly, resinous.	yellow.
Stilpnomelane	476	3 - 4	2.7- 3	pearly, bronze.	black to bronze, [var.
2. FUSIBILITY DIFFICULT.					
Talc	479	1 - 1.5	2.5- 2.8	pearly, earthy.	white, variable.
Pyrophyllite	482	1 - 2	2.7- 2.9	pearly.	white, variable.
Prochlorite	475	1 - 2	2.7- 2.9	pearly.	green.
Jefferisite	476	1.5	2.3	pearly.	yellowish [brown.
{ Clinochlore	473	2 - 2.5	2.6- 2.8	pearly.	green.
{ Penninite	474	2 - 3	2.6- 2.8	pearly, vitreous.	green, variable.
Margarodite	465	2 - 3	2.8- 3.1	pearly.	white.
Margarite	470	3.5- 4.5	2.9- 3	pearly, vitreous.	gray, red, yellow.
Chloritoid	481	5.5- 6.5	3.5- 3.6	pearly.	gray, green, [black.
3. INFUSIBLE.					
Kaolinite	481	1 - 2.5	2.4- 2.6	pearly, earthy.	white, variable.
Brucite	351	2.5	2.3- 2-4	pearly, vitreous.	white.
Paragonite	467	2.5- 3	2.7- 2.9	pearly.	yellow to green.
Seybertite	471	4 - 5	3 - 3.1	pearly.	brown, red.

°Sometimes used as a gem stone.

REMARKS.	CLEAVAGE OR FRACTURE.	CRYSTAL SYSTEM.	COMPOSITION.
The precious stone called Tiger Eye is a quartz pseudomorph after crocidolite.	F. fibrous.		$NaCa B_5 O_9$. 8 H_2O.
	F. fibrous.		$[Fe_4 (OH)_6] (Ca OH)_3 (As O_4)_3$.
The true specific gravity of fibrous substances can be obtained only by boiling or exhaustion under an air-pump.	F. splintery.	Ortho.	$H (Mn Mg Zn) BO_3$.
	C. foliated.		$H_6 (Fe Mg)_2 (Fe Al)_2 Si_5 O_{18}$.
See notes on Serpentine, p. 2, and Brucite, p. 3.	F. fibrous.		$(Na Fe) (Ca Mg Fe) (Si O_3)_3$.
Asbestos is a finely fibrous form of several minerals of the amphibole pyroxene group and their decomposition products; hence its chemical and physical characters vary. It is used for packing, fire-proof cloth, paint, non-conducting material, etc.	F. uneven.		$H_4 (Mg Fe)_3 Si_2 O_9$.
	C. basal.	Hex.	$Mg (OH)_2$.

V—BRITTLE MINERALS,

(a) STREAK

REMARKS.	CLEAVAGE OR FRACTURE.	CRYSTAL SYSTEM.	COMPOSITION.
Pyrrhotite is an important ore of nickel.	C. pinacoidal.	Mono.	$(Au Ag) Te_2$.
	C. pinacoidal.	Ortho.	$Bi_2 S_3$.
	C. pinacoidal.	Ortho.	$Sb_2 S_3$.
Marcasite is responsible for most of the dark brown stains on stone buildings.	C. basal.	Hex.	Bi.
	F. uneven.	Ortho.	$3 (Pb Cu_2) S$. $Bi_2 S_3$.
	F. uneven.	Mono.	$5 (Pb Ag_2) S$. $2 Sb_2 S_3$.
	C. prismatic.	Ortho.	5 Pb S. $Sb_2 S_3$.
Tetrahedrite also frequently carries silver.	F. uneven.	Tri.	$(Au Ag) Te_2$.
	F. uneven.	Mono.	5 Pb S. 4 $Sb_2 S_3$.
	C. pinacoidal.	Ortho.	4 Pb S. $Sb_2 S_3$.
Pyrite is often the gangue of gold. It is used in the manufacture of alums, paint and sulphuric acid.			$(Pb Cu_2) Se$.
	C. cubic.	Iso.	Pb S.
	F. uneven	Ortho.	$Cu_2 S$.
	C. cubic.	Iso.	Pb Se.
	F. uneven.	Ortho.	2 Pb S. $Cu_2 S$. $Sb_2 S_3$.
Bismuth is used in alloys: in the manufacture of optical glass; in coloring porcelain; and in medicine.			3 Pb S. $Sb_2 S_3$.
	F. uneven.	Ortho.	Cu Ag S.
			$(Cu Tl Ag)_2 Se$.
			Fe S. $Sb_2 S_3$.
	C. basal.	Hex.	Sb.
Galena is now the principal ore of lead.	F. uneven.	Ortho.	Pb S. $Sb_2 S_3$.
	F. uneven.	Iso.	4 Cu S. $Sb_2 S_3$.
	C. prismatic.	Ortho.	Fe As S.
Lead is used in the manufacture of paint, glazes for pottery, glass, and alloys; as a flux in metallurgical processes; in the form of sheets, pipes and shot, and in medicine.	F. uneven.	Tet.	$Cu Fe S_2$.
	F. uneven.	Hex.	Fe S.
	C. cubic.	Iso.	Co As S.
	F. uneven.	Mono.	variable.
	F. uneven.	Iso.	$Fe S_2$.
	F. uneven.	Ortho.	$Fe S_2$.
	F. uneven.	Iso.	$Ca Ti O_3$.
	F. uneven.	Ortho.	$Ti O_2$.
	C. octahedral.	Iso.	$Ru S_2$.

NAME.	PAGE IN DANA.	HARDNESS.	GRAVITY.	LUSTRE.	COLOR.
(a) FUSIBILITY EASY.					
Ulexite.	520	1	1.6	silky.	white.
Arseniosiderite.	506	1 - 2	3.5- 3.8	silky.	yellowish [brown.
Sussexite.	518	3	3.4	silky, pearly.	gray to white.
Stilpnomelane	476	3 - 4	2.7- 3	pearly, vitreous.	black to bronze [var.
°Crocidolite	404	4	3.2- 3.3	silky.	blue to green.
(b) FUSIBILITY DIFFICULT.					
°Serpentine.	476	2.5- 5.5	2.2- 2.6	silky, var.	white to yellow [var.
*Chrysotile Asbestos	401	2.5- 5	2.5- 2.6	silky.	white to gray.
(c) INFUSIBLE.					
Brucite	351	2.5	2.3- 2.4	silky, pearly, [vitreous.	white.

METALLIC LUSTRE.

GRAY.

NAME.	PAGE IN DANA.	HARDNESS.	GRAVITY.	COLOR.
1. EASILY FUSIBLE.				
Sylvanite	304	1.5- 2	8 - 8.3	gray to white.
Bismuthinite	284	2	6.4- 7.2	gray.
Stibnite	283	2	4.5- 4.6	gray.
Bismuth	275	2 - 2.5	9.7- 9.8	white, red.
Aikenite	310	2 - 2.5	6.1- 6.8	gray.
Frieslebenite	309	2 - 2.5	6.2- 6.4	steel gray.
Geocronite	314	2 - 3	6.4	lead gray.
Calaverite	305	2 - 3	9	yellow, white.
Plagionite	308	2.5	5.4	black to gray.
Meneghinite	313	2.5	6.3- 6-4	lead gray.
Zorgite	289	2.5	7 - 7.5	lead gray.
Galena	287	2.5- 2.7	7.2- 7.7	lead gray.
Chalcocite	290	2.5- 3	5.5- 5.8	blackish.
Clausthalite	288	2.5- 3	7.6- 8.8	lead gray.
Bournonite	310	2.5- 3	5.7- 5.9	steel gray, black.
Boulangerite	309	2.5- 3	5.7- 6	bluish gray.
Stromeyerite	290	2.5- 3	6 - 6-3	steel gray.
Crookesite	289	2.5- 3	6.9	lead gray.
Berthierite	308	3	4.1	steel gray.
Antimony	275	3 - 3.5	6.6- 6.7	tin white.
Zinkenite	307	3 - 3.5	5.3- 5.4	steel gray.
Tetrahedrite	312	3 - 4	4 - 5	iron black.
Arsenopyrite	303	5.5- 6	5.9- 6.4	silver white, gray.
2. MEDIUM FUSIBILITY.				
Chalcopyrite	297	3.5- 4	4.1- 4.3	brass yellow.
Pyrrhotite	296	3.5- 4.5	4.4- 4.7	yellow, red.
Cobaltite	301	5.5	6 - 6.3	white, reddish.
°Allanite	440	5.5- 6	3 - 4.2	brown, black, var.
Marcasite	302	6 - 6.5	4.6- 4.9	bronze yellow.
°Pyrite	300	6 - 6.5	4.8- 5.2	brass yellow.
3. INFUSIBLE.				
Perovskite	487	5.5	4	yellow to black.
°Brookite	347	5.5- 6	3.8- 4	brown, black.
Laurite	302	7 - 7.5	7	black.

---

*An asbestiform variety of serpentine whose long fibres make it valuable for the manufacture of cloth.

°Sometimes used as a gem stone.

REMARKS.	CLEAVAGE OR FRACTURE.	CRYSTAL SYSTEM.	COMPOSITION.
Millerite resembles marcasite, but may be distinguished by its hardness and its nickel-content.	C. basal.	Hex.	$Cu\ S$.
			$(Pb\ Hg)\ Se$.
	F. uneven.	Ortho.	$5\ Ag_2 S.\ Sb_2 S_3$.
	C. basal.	Ortho.	$2\ Pb\ S.\ Sb_2 S_3$.
	F. uneven.	Mono.	$9\ (Ag\ Cu)_2\ S.\ Sb_2\ S_3$.
Cobaltite is now the principal ore of cobalt, which is used in the manufacture of pigments, in making glass, pottery, enamel, and for tinting paper and other substances.	F. conchoidal.	Iso.	$Hg\ Se$.
			$(Ag\ Au)_2\ Te$.
	F. uneven.	Ortho.	$Cu_2\ S$.
			$2\ Pb\ S.\ (Bi\ Sb)_2\ S_3$.
	C. basal.	Ortho.	$Pb\ S.\ As_2\ S_3$.
	C. basal.	Ortho.	$2\ Pb\ S.\ As_2\ S_3$.
	C. prismatic.	Ortho.	$3\ Cu_2\ S.\ As_2\ S_3$.
Pyrolusite is now the principal ore of manganese, which is used in the manufacture of steel, pottery and glass, and in dyeing, bleaching, and as a disinfectant.	F. uneven.	Iso.	$Cu_3\ Fe\ S_3$.
	F. uneven.	Iso.	$Hg\ S$.
	C. rhombohedral.	Hex.	$Ni\ S$.
	F. uneven.	Iso.	$4\ Cu_2\ S.\ Sb_2\ S_3$.
	C. basal.	Ortho.	$Cu_2\ S.\ Sb_2\ S_3$.
			$Cu_2\ S.\ Fe\ S.\ Sn\ S_2$.
	F. uneven.	Iso.	$(Ni\ Fe)\ S$.
Pyrolusite is usually found mixed with psilomelane.	F. uneven.	Iso.	$Ni\ (As\ Sb)\ S$.
	C. prismatic.	Ortho.	$Ni\ (As\ Sb)\ S$.
	C. prismatic.	Ortho.	$Co\ (As\ Bi)\ S$.
Niccolite is now the principal ore of nickel, which is largely used in plating, the manufacture of alloys, and in making nickel steel.	F. uneven.	Hex.	$Ni\ As$.
	C. cubic.	Iso.	$Ni\ Sb\ S$.
	F. uneven.	Iso.	$(Co\ Ni)_3\ S_4$.
	C. cubic.	Iso.	$Ni\ As\ S$.
	C. basal.	Mono.	$Cu\ O$.
Wolframite is a prominent ore of tungsten, which is used in hardening steel, and plaster-of-paris, as a mordant in dyeing, in making non-inflammable cloth, and in the manufacture of tungstic acid.	F. uneven.	Tet.	$Cu\ Fe\ S_2$.
	F. uneven.	Hex.	$Fe\ S$.
	F. uneven.	Tet.	$(Fe\ Mn)\ WO_4$.
	C. cubic.	Iso.	$Co\ As\ S$.
	C. basal.	Ortho.	$(Co\ Fe)\ As\ S$.
	C. prismatic.	Ortho.	$Fe\ As\ S$.
	C. octahedral.	Iso.	$Co\ As_2$.
	F. uneven.	Iso.	$Co\ As_3$.
Arseniopyrite is now the principal ore of arsenic, which is used in dyeing, in the manufacture of shot, insecticides, pigments, glass, alloys, steel which will take a brilliant polish, and in medicine.	F. uneven.	Ortho.	$Ca\ Fe_2\ (FeOH)\ (SiO_4)_2$.
	F. uneven.	Ortho.	$Fe\ S_2$.
	F. uneven.	Iso.	$Fe\ S_2$.
	C. basal.	Mono.	$Cu_3\ Mn_4\ O_9$.
	C. basal.	Ortho.	$Fe\ As_2$.
	F. conchoidal.	Hex.	$(Fe\ Ti)_2\ O_3$.
	F. uneven.	Iso.	$Fe_3\ O_4$.
Graphite. See note, p. 3.	F. uneven.	Iso.	$U\ O_3$, etc.
	C. basal.	Hex.	C.
			$Mn\ O_2$.
	C. basal.	Mono.	$Cu\ O$.
	C. pinacoidal.	Ortho.	$Mn_2\ O_3.\ H_2O$.
	F. conchoidal.	Hex.	$(Fe\ Ti)_2\ O_3$.
			$Mn\ O_2$.
	F. uneven.	Iso.	$(Fe\ Zn\ Mn)\ O.\ (Fe\ Mn)_2\ O_3$.
	F. uneven.	Iso.	$Fe_3\ O_4$.
	F. uneven.	Iso.	$U\ O_3$, etc.
	F. uneven.	Iso.	$(Mn\ Mg)\ O.\ (Fe\ Mn)_2\ O_3$.
	F. uneven.	Ortho.	$(Fe\ Mn)\ (Nb\ Ta)_2\ O_6$.
	F. uneven.	Iso.	$Mg\ Fe_2\ O_4$.
	F. uneven.	Hex.	$(Mg\ Fe)\ Ti\ O_3$.

BLACK.

NAME.	PAGE IN DANA.	HARDNESS.	GRAVITY.	COLOR.
1. EASILY FUSIBLE.				
Covellite	294	1.5- 2	4.5- 4.6	blue to black.
Lehrbachite	289	2	7.8	lead gray (Vol.)
Stephanite	314	2 - 2.5	6.2- 6.3	iron black.
Jamesonite	308	2 - 3	5.5- 6	black.
Polybasite	314	2 - 3	6 - 6.2	iron black.
Tiemannite	292	2.5	7.2- 8.5	lead gray (Vol.)
Petzite	289	2.5- 3	8.7- 9.4	iron black.
Chalcocite	290	2.5- 3	5.5- 5.8	blackish.
Kobellite	309	2.5- 3	6.3	gray.
Sartorite	308	3	5.3- 5.4	gray.
Dufrenoysite	309	3	5.5- 5.6	gray, black.
Enargite	314	3	4.3- 4.4	gray to black.
Bornite	297	3	4.4- 5.5	red, brown.
Metacinnabarite	292	3	7.7- 7.8	steel gray (Vol.)
Millerite	295	3 - 3.5	4.6- 5.6	brownish yellow.
Tetrahedrite	312	3 - 4.5	4 - 5	gray, iron black.
Chalcostibite	308	3 - 4	4.7	lead gray.
Stannite	315	3.5- 4	4.3- 4.5	steel gray.
Pentlandite	293	3.5- 4	4.9- 5	yellow.
Corynite	302	4.5- 5	6	gray to white.
Wolfachite	304	4.5- 5	6.3	silver white.
Alloclasite	304	4.5	6.6	steel gray.
Niccolite	295	5 - 5.5	7.3- 7.7	copper red.
Ullmannite	302	5 - 5.5	6.2- 6.7	silver white.
Linnaeite	297	5.5	4.8- 5	steel gray.
Gersdorffite	302	5.5	5.6- 6.9	silver white.
2. MEDIUM FUSIBILITY.				
Tenorite	332	3 - 4	5.8-6.25	iron black.
Chalcopyrite	297	3.5- 4	4.1- 4.3	brass yellow.
Pyrrhotite	296	3.5- 4.5	4.4- 4.7	yellow to red.
Wolframite	539	5 - 5.5	7.1- 7.5	gray to black.
Cobaltite	301	5.5	6 - 6.3	white, reddish.
Glaucodot	304	5 - 6	5.9- 6.2	silver white.
Arsenopyrite	303	5.5- 6	5.9- 6.4	silver white to gray.
Smaltite	301	5.5- 6	6.4- 7.2	tin white.
Skutterudite	302	5.5- 6	6.7- 6.8	whitish gray.
Ilvaite	445	5.5- 6	3.7- 4.2	black.
Marcasite	302	6 - 6.5	4.6- 4.9	bronze yellow.
°Pyrite	300	6 - 6.5	4.8- 5.2	brass yellow.
3. DIFFICULTY FUSIBLE.				
Crednerite	343	4.5	4.9- 5.1	black.
Lollingite	303	5.5	6.8- 8.7	silver white.
Menaccanite	336	5 - 6	4.5- 5	iron black.
Magnetite	339	5.5- 6.5	4.9- 5.2	iron black.
Uraninite	521	5.5	6.4- 9.7	brown to black.
4. INFUSIBLE.				
Graphite	273	1 - 2	2 - 2.2	black.
Pyrolusite	347	2 - 2.5	4.7- 4.8	black.
Tenorite	332	3 - 4	5.8-6.25	iron black.
Manganite	349	4	4.2- 4.4	gray, black.
Menaccanite	336	5 - 6	4.5- 5	iron black.
Psilomelane	352	5 - 6	3.7- 4.7	black.
Franklinite	341	5.5- 6.5	5 - 5.2	black.
°Magnetite	339	5.5- 6.5	4.9- 5.2	iron black.
Ilmenite	269	5.5- 6	4.3- 3	black.
Uraninite	521	5.5	6.4- 9.7	brown to black.
Jacobsite	341	6	4.75	black.
Columbite	490	6	5.4- 7.5	iron black to gray.
Magnesioferrite	341	6 - 6.5	4.5- 4.6	iron black.

°Sometimes used as a gem stone.

REMARKS.	CLEAVAGE OR FRACTURE.	CRYSTAL SYSTEM.	COMPOSITION.
			(c) STREAK
Chalcopyrite. See note on copper, p. 1.	C. cubic.	Iso.	MnS.
	F. uneven.	Tet.	$CuFeS_2$.
			(d) STREAK
Binnite, cubanite. See note on copper, p. 1.	F. uneven.	Mono.	$Ag_2S.\ Sb_2S_3$.
	F. conchoidal.	Hex.	$3\ Ag_2S.\ Sb_2S_3$.
	F. conchoidal.	Iso.	$3\ Cu_2S.\ 2\ As_2S_3$.
Hematite. See note, p. 6.	C. cubic.	Iso.	$CuFe_2S_4$.
Columbite. See note on manganese, p. 5.	F. uneven.	Iso.	MnS_2.
			$2\ Fe_2O_3.\ H_2O$.
	F. uneven.	Hex.	Fe_2O_3.
	F. uneven.	Ortho.	$(FeMn)(NbTa)_2O_6$.
			(e) STREAK
See note on Millerite, p. 5. Most of our red, brown and yellow native paint pigments are hematite or limonite, with more or less clay, and occasionally some manganese. Note the close relationship between gothite and limonite. The former is crystalline and contains less water. Both are formed by the oxidation of iron-bearing minerals and the hydration of iron oxides.	F. uneven.	Tri.	$AuTe_2$.
	C. rhombohedral.	Hex.	NiS.
			$Fe_2O_3.\ 3\ H_2O$.
	C. pinacoidal.	Ortho.	$2\ Fe_2O_3.\ 2H_2O$.
			(f) STREAK
Chromite is usually associated with serpentine or talc. Both ore and gangue are derived from alteration of basic crystalline rocks.	C. basal.	Ortho.	$PbS.\ As_2S_3$.
	C. basal.	Ortho.	$2\ PbS.\ As_2S_3$.
	F. uneven.	Hex.	$NiAs$.
	F. uneven.	Tet.	$(FeMn)\ WO_4$.
	F. uneven.	Hex.	$NiSb$.
Chromite is used in the manufacture of glass, pigments and chrome steel, in calico printing and in galvanic batteries.	C. pinacoidal.	Ortho.	$Mn_2O_3.\ H_2O$.
			$Fe_2O_3.\ 3\ H_2O$.
	F. uneven.	Iso.	$Fe\ Cr_2O_4$.
	F. uneven.	Iso.	$(FeZnMn)O(FeMn)_2O_3$.
Rutile is now the principal ore of titanium, which is used in the manufacture of steel, porcelain and artificial teeth.			MnO_2.
	C. basal, pyramidal	Tet.	TiO_2.
	F. uneven.	Ortho.	$(FeMn)(TaNb)_2O_6$.
	F. uneven.	Ortho.	Nb Ti Y, etc.
			(g) STREAK
Bismuth. See note, p. 4.	C. pinacoidal.	Mono.	$(AuAg)Te_2$.
	C. pinacoidal.	Ortho.	$Cu_2S.\ Bi_2S_3$.
Antimony. See note, p. 1.	C. prismatic.	Hex.	Te.
	C. basal, rhombohedral.	Hex.	Bi.
Arsenic. See note on arsenopyrite, p. 5.	C. basal.	Hex.	Sb.
			Cu_3As.
		Iso.	Hg. Ag.
Octahedrite. See note on rutile, p. 6.	C. basal.	Hex.	As.
	C. basal.	Ortho.	Ag_3Sb.
	C. basal. pyramidal	Tet.	TiO_2.

GREEN.

NAME.	PAGE IN DANA.	HARDNESS.	GRAVITY.	COLOR.
1. FUSIBLE.				
Alabandite	292	3.5- 4	3.9- 4	black.
Chalcopyrite	297	3.5- 4	4.1- 4.3	brass yellow.
RED.				
1. EASILY FUSIBLE.				
Miargyrite	308	2 - 2.5	5.2- 5.4	iron black, gray.
Pyrargyrite	311	2 - 2.5	5.7- 5.9	red to black.
Binnite	308	2.5- 3	4.5	black.
Cubanite	297	4	4.1	bronze yellow.
2. MEDIUM FUSIBILITY.				
Hauerite	301	4	3.4	brownish black.
3. INFUSIBLE.				
Turgite	350	5 - 6	3.5- 4.7	red.
°Hematite	334	5.5- 6.5	4.5- 5.3	steel gray to black.
Columbite	490	6	5.4- 7.5	iron black to gray.
YELLOW.				
1. EASILY FUSIBLE.				
Calaverite	305	2 - 3	9	yellow, white.
Millerite	295	3 - 3.5	4.6- 5.6	brownish yellow.
2. INFUSIBLE.				
Limonite	350	5 - 5.5	3.6- 4	brown, yellow, black.
Göthite	349	5 - 5.5	4 - 4.4	yellow, brown, black.
BROWN.				
1. EASILY FUSIBLE.				
Sartorite	308	3	5.2- 5.4	dark gray.
Dufrenoysite	309	3	5.5- 5.6	blackish.
Niccolite	295	5 - 5.5	7.3- 7.7	red.
Wolframite	539	5 - 5.5	7.1- 7.5	gray black.
Breithauptite	296	5.5	7.5	copper red.
2. INFUSIBLE, OR DIFFICULTLY FUSIBLE				
Manganite	349	4	4.2- 4.4	steel gray to black.
Limonite	350	5 - 5.5	3.6- 4	brown, yellow, black.
Chromite	341	5.5	4.3- 4.5	black.
Franklinite	341	5.5- 6.5	5 - 5.2	iron black.
Psilomelane	352	5 - 6	3.7- 4.7	black.
°Rutile	345	6 - 6.5	4 - 4.2	yellow to black, var.
Tantalite	490	6 - 6.5	6.5- 7.5	iron black.
Euxinite	493	6.5	4.6- 5	brown to black.
WHITE.				
1. EASILY FUSIBLE.				
Sylvanite	304	1.5- 2	7.9- 8.3	gray to white.
Emplectite	308	2	6.3- 6.5	tin white.
Tellurium	275	2 - 2.5	6.1- 6.3	white.
Bismuth (cold)	275	2 - 2.5	9.7- 9.8	white.
Antimony	275	3 - 3.5	6.6- 6.7	white (Vol.)
Domeykite	286	3 - 3.5	7 - 7.5	white.
Amalgam	279	3 - 3.5	13.7-14	white.
Arsenic	274	3.5	5.6- 5.7	white (Vol.)
Dyscrasite	286	3.5- 4	9.4- 9.8	white.
2 INFUSIBLE.				
°Octahedrite	346	5.5- 6	3.8- 4.1	brown to black, var.

---

*Hematite sometimes fuses slightly on thin edges.
°Sometimes used as a gem stone.

BRITTLE MINERALS, SOLUBLE IN WATER.

REMARKS.	CLEAVAGE OR FRACTURE.	CRYSTAL SYSTEM.	COMPOSITION.
Borax is used as a flux in metallurgy, in the manufacture of pottery glazes, glass, paste gems, and as an antiseptic in medicine.	C. pinacoidal.	Mono.	$K_2 Ca_2 Mg (SO_4)_4 . 2 H_2O$.
	C. basal.	Tri.	$B (OH)_3$.
	F. conchoidal.	Ortho.	$Mg K Cl_3 . 6 H_2O$.
	C. prismatic.	Ortho.	$K NO_3$.
	C. rhombohebral.	Hex.	$Na NO_3$.
Niter, soda niter, kainite, etc., are much used as fertilizers. The first two are also used in making gunpowder and as preservatives.	C. pinacoidal.	Mono.	$Na_2 SO_4 . 10 H_2O$.
		Mono.	$Al_2 SO_4 . 18 H_2O$.
	C. cubic.	Iso.	$K Cl$.
	C. basal.	Mono.	$Fe SO_4 . 7 H_2O$.
	C. pinacoidal.	Mono.	$Na_2 B_4 O_7 . 10 H_2O$.
	C. pinacoidal.	Ortho.	$Mg SO_4 . 7 H_2O$.
Halite is the source of common salt.	F. conchoidal.	Iso.	$K Al (SO_4)_2 . 12 H_2O$.
	C. cubic.	Iso.	$Na Cl$.
	F. conchoidal.	Tri.	$Cn SO_4 . 5 H_2O$.
	C. pinacoidal.	Mono.	$Na_2CO_3 . H NaCO_3 . 2 H_2O$
	C. prismatic.	Mono.	$Mg SO_4 . K Cl . 3H_2O$.
	C. pyramidal.	Mono.	$Mg SO_4 . H_2O$.

BRITTLE MINERALS, INSOLUBLE IN WATER.

REMARKS.	CLEAVAGE OR FRACTURE.	CRYSTAL SYSTEM.	COMPOSITION.
Glauconite is much used as a fertilizer for lands needing potash. It is formed by the decomposition of sedimentary rocks. Now forming off the coast of Georgia.			$K . Fe . SiO_2$.
			$BiO . Bi (OH)_2 . CO_3$.
	C. basal.	Tri.	$Ti (Al F) PO_4$.
	C. prismatic.	Mono.	$Na Fe (SiO_3)_2$.
Black tourmaline is easily mistaken for hornblende and augite, but is distinguished by the test for boron. The light-colored, transparent varieties are used as precious stones.	C. prismatic.	Mono.	$Ca Ti SO_5$.
	C. pinacoidal.	Ortho.	$Mn_2 SiO_4$.
	F. uneven.	Iso.	Be, Fe, Zn, Mn, S & SiO_2.
	F. uneven.	Mono.	Ca, Fe, Al, Ce, La & SiO_2.
The finer specimens of epidote are used as gem stones.	C. basal.	Mono.	$Ca (Al OH) (Al Fe)_2 (SiO_4)_3$.
	F. conchoidal.	Hex.	Al, Fe, Mg, Mn, Na, H, F, SiO_2.
Amblygonite is a source of lithium.			$H_6 K_2 Al_2 (SiO_4)_5$.
See note on pinite, p. 2.	C. pinacoidal.	Ortho.	$Mg Fe SiO_3$.
Note the close relationship between enstatite, Bronzite and Hypersthene; also between these and the members of the amphibole pyroxene group. p. 8.	C. prismatic.	Ortho.	$Mg Fe SiO_3$.
	C. basal.	Mono.	$H_2 Fe Al_2 SiO_7$.
	F. uneven.	Iso.	$Ca Ti O_3$.
Massicot and Minium are used as pigments.			$[Fe_4 (OH)_6] (Ca OH)_2 (AsO_4)_3$.
			$Pb O$.
	C. basal.	Ortho.	$Ca (UO_2)_2 (PO_4)_2 . 8 H_2O$.
Descloizite. See note, p. 8.			$Pb_3 O_4$.
	F. uneven.	Iso.	$Fe (FeOH)_3 (As O_4)_3 . 6 H_2O$.
	F. uneven.	Ortho.	$Pb . (Pb OH) VO_4$.
	C. dodecahedral.	Iso.	$Zn Fe S$.
	C. two directions.	Mono.	$(Ca Mg) F . (Fe Mn) PO_4$
	C. prismatic.	Mono.	$Na (Al F) As O_4$.

NON-METALLIC LUSTRE.
Easily Fusible.

Name.	Page in Dana.	Hardness.	Gravity.	Lustre.	Color.
1. Streak Red.					
Polyhalite	535	2.5- 3	2.7	resinous, pearly.	red, yellow.
2 Streak White.					
Sassolite	352	1	1.5	pearly.	white.
Carnallite	323	1	1.6	greasy.	white, variable.
Niter	517	1.5- 2	2.1- 2.3	vitreous.	white, variable.
Soda Niter	379	1.5- 2	2.2- 2.3	vitreous.	white, variable.
Mirabilite	531	1.5- 2	1.4- 1.5	vitreous.	white.
Alunogen	395	1.5- 2	1.6- 1.8	vitreous.	white, var.
Sylvite	318	2	1.9- 2	vitreous.	white.
Melanterite	534	2	1.9		green.
Borax	520	2 - 2.5	1.6- 1.7	vitreous, resinous	white, variable.
Epsomite	533	2 - 2.5	1.6- 1.7	vitreous.	white.
Kalinite	535	2 - 2.5	1.7		white.
Halite	318	2.5	2.1- 2.6	vitreous.	white, variable
Chalcanthite	534	2.5	2.1- 2.3	vitreous.	blue.
Trona	367	2.5- 3	2.1	vitreous.	gray to yellow.
Kainite	530	2 5- 3	2 - 2.2	vitreous.	white, red.
Kieserite	394	3- 3.5	2.5	vitreous.	white.

NON-METALLIC LUSTRE.
Streak Colored. Fusible.

Name.	Page in Dana.	Hardness.	Gravity.	Lustre.	Color.
1. Streak Gray.					
(a) Fusibility Easy.					
Glauconite	349	2	2.2- 2.4	dull.	green.
Bismutite	367	4 - 4.5	6.8- 6.9	vitreous.	white to green, [yellow.
Amblygonite	503	6	3 - 3.1	pearly, vitreous.	white to green, [var.
Acmite	391	6 - 6.5	3.5	vitreous.	brown, green.
(b) Fusibility Medium.					
°Titanite	485	5 - 5.5	3.4- 3.5	adamantine, [resinous.	brown, green, [black, var.
Tephroite	422	5.5- 6	4 - 4.1	adamantine.	gray to red.
Danalite	414	5.5- 6	3.4	vitreous, resinous	gray to red.
°Allanite	440	5.5- 6	3 - 4.2	submetallic, [resinous.	brown, black, [variable.
°Epidote	438	6 - 7	3.2- 3.5	vitreous.	green, black, [var.
°Tourmaline	447	7 - 7.5	2.9- 3.3	vitreous.	black, brown, [var.
(c) Fusibility Difficult.					
Pinite	466	2 5- 3.5	2.6- 2.8	pearly.	gray, green, red, [var.
°Hypersthene	385	5 - 6	3.4- 3.5	pearly.	green, brown, [black.
°Bronzite	385	5.5	3.1- 3.3	pearly, bronze.	green, bronze.
Chloritoid	471	6.5	3.5	pearly.	gray, green, [black.
(d) Infusible.					
Perovskite	487	5	4	adamantine.	yellow, black.
2. Streak Yellow.					
(a) Fusibility Easy.					
Arseniosiderite	506	1 - 2	3.5- 3.8	silky.	yellow, brown.
Massicot	332	2	7.8- 9.3	dull.	yellow.
Autunite	515	2 - 2.5	3 - 3.1	pearly, adamantine.	yellow.
Minium	343	2 - 3	4.6	greasy.	red to yellow.
Pharmacosiderite	513	2.5	2.9- 3	adamantine, [resinous.	red to yellow, [green, brown,
Descloizite	505	3.5	5.8- 6.2	bronze.	black, brown, red.
°Sphalerite	291	3.5- 4	3.9- 4.2	resinous, adamantine.	brown, red, var.
Triplite	502	4 - 5.5	3.4- 3.8	resinous.	brown to black, [red.
Durangite	503	5	4	vitreous.	red.

°Sometimes used as a gem stone.

REMARKS.	CLEAVAGE OR FRACTURE.	CRYSTAL SYSTEM.	COMPOSITION.
Malachite and Azurite always occur as alteration products of other ores of copper, usually of sulphides. They are often deposited from solution. They are often polished and used as ornamental stones.	C. pinacoidal.	Mono.	$As_2 S_3$.
			$Fe_2(OH)_3PO_4 . 4\frac{1}{2} H_2O$
	C. one direction.	Mono.	$H_{12} Na_2 Ca_{10} Ce_2 [(Ti Zr)(OH, F)_2]_4(SiO_4)_{12}$.
	C. dodecahedral.	Iso.	$(Zn Fe) S$.
	C. basal.	Mono.	$Ca_2 (Al OH) (Al Fe)_2 (SiO_4)_3$.
Cinnabar is now the principal ore of mercury, which is used in the manufacture of mirrors, in metallurgy, various amalgams and alloys, physical instruments, in the manufacture of pigments and in medicine.			$K. Fe SiO_2$.
	F. uneven.	Iso.	$Fe (Fe OH)_3 (AsO_4)_3 . 6 H_2O$.
	C. basal.	Mono.	$Cu (OH)_3 AsO_4$.
	F. uneven.	Mono.	$(Pb Cu)_3 (PO_4)_2 2 (Pb Cu) Cr O_4$.
	F. uneven.	Ortho.	$Cu (Cu OH) AsO_4$.
Descloizite and Vanadinite are the principal sources of vanadium, which is used in dyeing and in the manufacture of steel and porcelain.	C. pinacoidal.	Ortho.	$Cu SO_4 . 3 Cu (OH)_2$.
	F. splintery.	Ortho.	$Fe_2 (OH)_3 PO_4$.
	C. basal.	Mono.	$Cu CO_3 . Cu (OH)_2$.
	F. uneven.	Ortho.	$Cu (Cu OH) PO_4$.
			$Bi O . (Bi 2 OH) C O_3$.
Nephrite is a tough variety with splintery fracture graduating between tremolite and actinolite.	F. uneven.	Mono.	$(Cu OH)_9 [Al_4 (OH)_6] (AsO_4)_5 . 20 H_2O$.
	C. pinacoidal.	Ortho.	$Cu Cl_2 . 3 Cu (OH)_2$.
		Mono.	
In all the hornblendes the cleavage angle is 124°30″. In all the pyroxenes the cleavage angle is 87°5″. The pyroxenes are more common in volcanic rocks, are less stable, and are gradually transformed into amphiboles. An intermediate variety called uralite has the external form of augite, and the internal arrangement of hornblende.			$Ca Mg SiO_3$.
			$(Ca Mg Fe) SiO_3$.
			$Na_2 Al_2 Si_4 O_{12}$.
			$Ca (Mg Fe)_3 Si_4 O_{12}$.
			$(Mg Fe)_2 (Al Fe)_4 Si_2 O_{12}$.
			$(Mg Fe)_3 Ca Si_4 O_{12}$.
			$Ca Mg Si_2 O_6$.
			$Ca (Mg Fe) Al_2 Si_2 O_9$.
			$(Ca Mg Fe) SiO_3$.
			$Ca Mg Si_2 O_6$.
			$Ca (Mg Fe) Al_2 Si_2 O_9$.
			$(Mg Fe) Ca Si_2 O_6$.
			$Ca Fe Si_2 O_6$.
			$(Mg Fe Zn) (Ca Mn) Si_2 O_6$.
	C. basal.	Mono.	$Ca (Al OH) (Al Fe)_2 (SiO_4)_3$.
	C. basal.		$H_{40} (Fe Mg)_{23} Al_{14} Si_{13} O_{90}$.
		Mono.	
	C. basal.	Mono.	$H_2 Fe Al_2 SiO_7$.

STREAK COLORED. FUSIBLE.

	NAME.	PAGE IN DANA.	HARDNESS.	GRAVITY.	LUSTRE.	COLOR.
	2. STREAK YELLOW.					
	(b) Fusibility Medium.					
	Orpiment	282	1.5- 2	3.4- 3.5	pearly to resinous.	yellow.
	Cacoxenite	513	3 - 4	2.3- 3.3	silky.	yellow to brown.
	Mosandrite	487	4	2.9- 3	vitreous, resinous, pearly.	reddish, brown, green.
	(c) Fusibility Difficult.					
	°Sphalerite	291	3.5- 4	3.9- 4.2	resinous, adamantine.	brown, red, var.
	°Epidote	438	6 - 7	3.2- 3.5	vitreous.	green, black, gray.
	3. STREAK GREEN.					
	(a) Fusibility Easy.					
	*Glauconite	481	2	2.2- 2.4		green.
	Pharmacosiderite	513	2.5	2.9- 3	adamantine, resinous.	green, yellow, red, brown.
	Clinoclasite	505	2.5- 3	4.1- 4.3	pearly, vitreous.	green.
	Vauquelinite	529	2.5- 3	5.5- 6.1	adamantine, resinous	green to black.
	Olivenite	504	3	4.1- 4.4	adamantine, vitreous.	green to brown.
	Brochantite	530	3.5- 4	3.7- 3.9	vitreous.	green.
	Dufrenite	506	3.5- 4	3.2- 3.4	silky.	green.
	°Malachite	365	3.5- 4	3.7- 4	adamantine, vitreous.	green.
	Libethenite	504	4	3.6- 3.8	resinous.	green.
	Bismutite	367	4 - 4.5	6.8- 7	vitreous.	white to green, var.
	(b) Fusibility Medium.					
	Liroconite	514	2 - 2.5	2.8- 3	vitreous.	green, blue.
	Atacamite	322	3 - 3.5	3.7	adamantine, vitreous.	green.
	Amphibole Pyroxene	399 387	4 - 6.5	2.9- 3.5	vitreous. pearly, resinous.	variable.
Amphibole.	Tremolite		5 - 6.5	2.9- 3.1		white, gray.
	Nephrite		6 - 6.5	2.9- 3.1		white, green, blue.
	Actinolite		5 - 6	3 - 3.2		green.
	Edenite		5	3		white, gray, green.
	°Smaragdite		5	3		grass green.
	Pargasite		5	3 - 3.5		green, bluish.
	°Hornblende		5	3 - 3.5		green, black.
Pyroxene	Malacolite °Diopside		5 - 5.5	3.2- 3.4		white to pale green.
	°Diallage		4	3.2- 3.3		bright green.
	Sahlite		4	3.2- 3.4		white, green, black.
	Leucaugite		6 - 6.5	3 - 3.2		white, gray.
	Fassaite		5 - 6	3.2- 3.5		green.
	°Augite		5 - 6	3.2- 3.5		brown, black.
	Hedenbergite		5 - 6	3.5- 3.6		black.
	Jeffersonite		5 - 6	3.3		black.
	°Epidote	438	6 - 7	3.2- 3.5	vitreous.	green, black, gray.
	(c) Fusibility Difficult.					
	Prochlorite	475	1 - 2	2.7- 2.9	pearly.	green.
	*Amphibole Pyroxene	399 387	4 - 6.5	2.9- 3.5	vitreous. pearly, resinous.	variable.
	°Chloritoid	471	6.5	3.5	pearly.	gray, green, red, var.

---

*For varieties see above.
°Sometimes used as a gem stone.

REMARKS.	CLEAVAGE OR FRACTURE.	CRYSTAL SYSTEM.	COMPOSITION.
	C. basal.	Hex.	$Cu S$.
	C. pinacoidal.	Mono.	$[(Pb Cu) OH]_2 SO_4$.
	F. conchoidal.	Mono.	$2 Cu CO_3. Cu (OH)_2$.
Cuprite, see note under copper, p. 1.	F. uneven.	Mono.	$(Cu OH)_9 [Al_4 (OH)_6] (As O_4)_5$.
	C. prismatic.	Mono.	$Na_2 Al_2 Mg_4. (SiO_3)_8 [20 H_2O$.
	C. pinacoidal.	Mono.	$As S$.
	C. pinacoidal.	Mono.	$Co_3 (AsO_4)_2. 8 H_2O$.
Arseniosiderite, see note under arsenic, p. 1.	F. uneven.	Mono.	$Ag_2 S. Sb_2 S_3$.
	F. conchoidal.	Hex.	$3 Ag_2 S. Sb_2 S_3$.
	F. conchoidal.	Hex.	$3 Ag_2 S. As_2 S_3$.
	C. prismatic.	Hex.	$Hg S$.
Sphalerite, a prominent ore of zinc, which is used for plating roofing, in alloys, as a pigment and in the manufacture of optical glass. It is also known as Blende and as Black Jack.	C. pinacoidal.	Mono.	$K_2 Ca_2 Mg (SO_4)_4. 2 H_2O$.
	F. uneven.	Ortho.	$Pb (Pb OH) VO_4$.
	F. uneven.	Ortho.	$Ca Fe_2 (Fe OH) (SiO_4)_2$.
	C. pinacoidal.	Ortho.	$2Pb CrO_4. PbO$.
	F. conchoidal.	Iso.	Cu_2O.
	C. basal.	Mono.	$Ca_2 (Al OH) (Al Mn Fe)_2 (SiO_4)_3$.
	C. dodecahedral.	Iso.	$Zn Fe S$.
Triplite, see note under pyrolusite, p. 5.			
			$[Fe_4 (OH)_6] (Ca OH)_3 (AsO_4)_3$.
	F. uneven.	Iso.	$Fe (Fe OH)_3 (AsO_4)_3. 6 H_2O$.
	F. uneven.	Mono.	$(Pb Cu)_3 (PO_4)_2. 2 (Pb Cu) Cr O_4$.
See note under Quartz, p. 16.			
	F. uneven.	Ortho.	$Cu (Cu OH) AsO_4$.
	C. two directions.	Mono.	$(Fe Mn) (Fe Mn F) PO_4$.
	C. pinacoidal.	Ortho.	$Fe_2 SiO_4$.
Garnet, see note p. 14.	C. one direction.	Mono.	$H_{12} Na_2 Ca_{10} Ce_2 [(Ti Zr) (OH F)_2]_4 (SiO_4)_{12}$
	C. pinacoidal.	Ortho.	$Mg Fe SiO_3$.
Hypersthene, see note p. 7.			
	C. dodecahedral.	Iso.	$Zn Fe S$.
	F. conchoidal.	Ortho.	$(Fe Ca UO_2)_3 (Ce Y)_2 (Nb Ta)_6 O_{21}$.
	F. conchoidal.	Hex.	SiO_2.

NAME.	PAGE IN DANA.	HARDNESS.	GRAVITY.	LUSTRE.	COLOR.
4. STREAK BLUE.					
(a) Fusibility Easy.					
Covellite	294	1.5- 2	4.5- 4.6	metallic, [adamantine.	indigo blue.
Linarite	530	2.5	5.3- 5.4	vitreous, [adamantine.	blue.
°Azurite	365	3.5- 4.2	3.5- 3.8	vitreous, [adamantine.	blue.
(b) Fusibility Medium.					
Liroconite	514	2 - 2.5	2.8- 3	vitreous.	blue to green.
Glaucophane	403	6 - 6.5	3.1	vitreous, pearly.	blue.
5. STREAK RED.					
(a) Fusibility Easy.					
Realgar	282	1.5- 2	3.4- 3.6	resinous.	red to yellow.
Erythrite	509	1.5- 2.5	2.9	vitreous, pearly.	peach red, gray.
Miargyrite	308	2 - 2.5	5.2- 5.4	metallic, ada- [mantine.	black, gray.
Pyargyrite	311	2 - 2.5	5.7- 5.9	metallic, ada- [mantine.	red to black.
Proustite	311	2 - 2.5	5.4- 5.6	adamantine.	red.
Cinnabar	293	2 - 2.5	8 - 8.2	adamantine.	red.
Polyhalite	535	2.5- 3	2.7	resinous, pearly.	red.
Descloizite	505	3.5	5.8- 6.2	bronze.	red, brown, [black.
Phoenicochroite	529	3 - 3.5	5.7	resinous, ada- [mantine.	red.
Cuprite	331	3.5- 4	5.8- 6.2	adamantine.	red.
(b) Fusibility Medium.					
Piedmonite	440	6.5	3.4	vitreous.	red to black.
(c) Fusibility Difficult.					
°Sphalerite	291	3.5- 4	3.9- 4.2	resinous, ada- [mantine.	brown, red, var.
6. STREAK BLACK.					
Ilvaite	445	5.5- 6	3.9- 4	sub-metallic.	black.
7. STREAK BROWN.					
(a) Fusibility Easy.					
Arseniosiderite	506	1 - 2	3.5- 3.8	silky.	brown, yellow.
Pharmacosiderite	513	2.5	2.9- 3	adamantine, [resinous.	red, brown, yellow, green.
Vauquelinite	529	2.5- 3	5.5- 6.1	adamantine, [resinous.	brown, black, [green.
Olivenite	504	3	4.1- 4.4	adamantine, [vitreous.	green to brown.
Triplite	502	4 - 5.5	3.4- 3.8	resinous.	brown, black.
Fayalite	422	6.5	4 - 4.1	resinous, sub- [metallic.	black.
(b) Fusibility Medium.					
Mosandrite	487	4	2.9- 3	vitreous, res- [inous.	red to brown [green.
†Amphibole	399	4 - 6.5	2.9- 3.5	pearly, resinous.	variable.
Pyroxene	387			vitreous.	
°Hypersthene	385	5 - 6	3.4- 3.5	pearly.	red, green, var.
*°Garnet	415	6.5- 7.5	3.1- 4.3	vitreous, resi- [nous.	green, brown, [black.
(c) Fusibility Difficult.					
Sphalerite	291	3.5- 4	3.9- 4.2	resinous, ada- [mantine.	brown, red, var.
†Amphibole	399	4 - 6.5	2.9- 3.5	pearly, resinous	variable.
Pyroxene	387			vitreous.	
Samarskite	492	5.5- 6	5.4- 5.7	vitreous, resinous.	black.
*Garnet	415	6.5- 7.5	3.1- 4.3	vitreous, resin- [ous.	red, green, var.
(d) Infusible.					
°Quartz	324	7	2.6	vitreous.	white, var.

*For varieties see p. 14.
†For varieties see p. 8.
°Sometimes used as a gem stone.

INSOLUBLE IN WATER.

REMARKS.	CLEAVAGE OR FRACTURE.	CRYSTAL SYSTEM.	COMPOSITION.
Cassiterite is now the principal ore of tin, which is largely used in plating, casting, alloys, polishing, dyeing, as an abrasive, a pigment, and in the manufacture of foil.	C. rhombohedral.	Hex.	$Fe\ CO_3$.
	F. conchoidal.	Ortho.	$(Fe\ Ca)\ (Y\ Er\ Ce)_2\ (Ta\ Nb)_4\ O_{15}$.
	C. prismatic.	Ortho.	$Mg\ Fe\ SiO_3$.
	F. uneven.	Iso.	$Ca\ Ti\ O_3$.
Rutile. See note, p. 6.	C prismatic.	Ortho.	$Mg\ Fe\ SiO_3$.
	F. uneven.	Iso.	$U\ O_3$, etc.
Bronzite, Enstatite. See note, p. 7.	F. uneven.	Ortho.	$Ti\ O_2$.
	C. prismatic.	Tet.	$Ti\ O_2$.
Brookite. See under Rutile, p. 6.			$Al_2(OH)_3\ PO_4.\ H_2O$.
	F. uneven.	Tet.	$Sn\ O_2$.
Perovskite. See under Rutile, p. 6.		Tet.	$Mn_2\ O_3.\ Mn\ SiO_3$.
Tourmaline. See note, p. 7.	F. conchoidal.	Mono.	$Fe\ Be_2\ Y_2\ Si_2\ O_{10}$.
	F. conchoidal.	Hex.	Al, Fe, Mg, B, Si, O.
Braunite. See note under Pyrolusite, p. 5.	C. pinacoidal.	Ortho.	$(Al\ O)_4\ (Al\ OH)\ Fe\ (SiO_4)_2$.
	F. conchoidal.	Iso.	$Zn\ Al_2\ O_4$.
Siderite, an important ore of iron.	F. conchoidal.	Iso.	$Mg\ Al_2\ O_4$.
	C. prismatic.	Hex.	$Cd\ S$.
The principal use of monazite is in the manufacture of mantels for gas-burners.	C. basal.	Hex.	$(Zn\ Mn)\ O$.
	C. prismatic.	Tet.	$Y\ PO_4$.
	F. uneven.	Hex.	$(Ce\ La\ Di)_2\ OF_4$.
	C. pinacoidal.	Ortho.	$Fe_2\ O_3.\ H_2O$.
	F. uneven.	Mono.	$(Ce\ La\ Di)\ PO_4$.
	F. conchoidal.	Iso.	Ta, Nb, Ca, Na, C, F, H.

STREAK COLORED. INFUSIBLE.

NAME.	PAGE IN DANA.	HARDNESS.	GRAVITY.	LUSTRE.	COLOR.
1. STREAK GRAY.					
Siderite	359	3.5- 4	3.8	vitreous.	gray, brown, [green.
Yttrotantalite	492	5 - 5.5	5.4- 5.9	submetallic, [greasy.	yellow to black, [gray, var.
°Enstatite	384	5.5	3.1- 3.3	vitreous.	gray, brown, [var.
Perovskite	487	5.5	4	adamantine.	yellow, brown, [black.
°Bronzite	385	5.5	3.1- 3.3	pearly, bronze.	green to brown.
Uraninite	521	5.5	6.4- 9.7	greasy, dull.	brown to black, [var.
°Brookite	347	5.5- 6	3.8- 4	adamantine.	brown black.
°Rutile	345	6 - 6.5	4.1- 4.2	adamantine.	yellow, black, [var.
°Turquois	512	6	2.6- 2.8	waxy.	blue, green.
°Cassiterite	344	6 - 7	6.4- 7.1	adamantine, [dull.	brown, black, [var.
Braunite	343	6 - 6.5	4.7- 4.8	sub-metallic.	brown, black, [gray.
°Gadolinite	436	6.5- 7	4 - 4.5	vitreous.	black.
°Tourmaline	447	7 - 7.5	2.9- 3.3	vitreous.	black, brown, [blue, var.
°Staurolite	450	7 - 7.5	3.6- 3.7	vitreous.	brown, black.
°Gahnite	339	7.5- 8	4 - 4.6	vitreous.	green, brown, [black, var.
°Spinel	338	8	3.5- 4.1	vitreous, dull.	black, variable.
2. STREAK YELLOW.					
Greenockite	294	3 - 3.5	4.8- 5	adamantine.	yellow.
Zincite	332	4 - 4.5	5.4- 5.7	sub-adamantine	red, yellow.
Xenotime	494	4 - 5	4.4- 4.5	resinous.	yellow to red, [var.
Fluocerite	322	4 - 5	5.7- 5.9	dull.	red to yellow.
Göthite	349	5 - 5.5	4 - 4.4	adamantine.	yellow to brown [black.
Monazite	495	5 - 5.5	4.9- 5.3	resinous.	red to brown.
°Microlite	489	5.5	5.5- 6.1	vitreous, resinous.	yellow to brown

°These are often used as gem stones.

REMARKS.	CLEAVAGE OR FRACTURE.	CRYSTAL SYSTEM.	COMPOSITION.
			$(Ni\,OH)_2\,CO_3.\ Ni\,(OH)_2.\ 4\,H_2O.$
Sphalerite. See note, p. 9.	C. rhombohedral.	Hex.	$H_2\,Cu\,SiO_4.$
	F. uneven.	Iso.	UO_2, etc.
Zaratite. See note under Niccolite, p. 5.			$Al\,(OH)_3\,PO_4.\ H_2O.$
	C. cubic.	Iso.	$Mg\,O.$
	F. conchoidal.	Mono.	$Fe\,Be_2\,Y_2\,Si_2\,O_{10}.$
Wad is an impure earthy mass, and consequently varies much in composition and properties. See note under pyrolusite, p. 5.	F. conchoidal.	Iso.	$Fe\,Al_2\,O_4.$
	C. prismatic.	Hex.	$Cd\,S.$
	C. prismatic.	Tet.	$Y\,PO_4.$
			$2\,Fe_2\,O_3.\ H_2O.$
			$Fe_2\,O_3.$
Braumite. See note under Pyrolusite, p. 5.	F. uneven.	Ortho.	$(Fe\,Mn)\,(Nb\,Ta)_2\,O_6.$
		Earthy.	Mn OH, etc.
	C. prismatic.	Hex.	$Zn\,S.$
Psilomelane. See note under Pyrolusite, p. 5.	C. dodecahedral.	Iso.	$Zn\,S.$
	C. prismatic.	Tet.	$Y\,PO_4.$
	F. conchoidal.	Iso.	Nb, Ti, Ca, Na, O, etc.
Rutile. See note, p. 6.	C. basal.	Tet.	$Mn_3\,O_4.$
			$Mn\,O_2$, etc.
	F. uneven.	Ortho.	Nb, Ti, Th, Ce, etc.
Cassiterite. See note, p. 10.	F. conchoidal.	Ortho.	Nb, Ti, Y, etc.
	F. uneven.	Mono.	Ta, Nb, Ca, Na, C, F, H.
Wurtzite. See under Sphalerite, p. 9.	C. rhombohedral.	Hex.	UO_2, etc.
	F. uneven.	Tet.	$(Y\,ErCe)\,(NbTa)\,O_4.$
	F. conchoidal.	Ortho.	Ca, Fe, U, Ce, Y, O, etc
Emery. See under Corundum, p. 17.		Iso.	$Fe_2\,O_3.$
	F. uneven.	Tet.	$Sn\,O_2.$
Hausmannite. See under Pyrolusite, p. 5.	C. prismatic.	Tet.	$Ti\,O_2.$
	C. pyramidal.	Tet.	$Mn\,O.\ Mn\,O_2.$
	F. conchoidal.	Ortho.	Nb, Zr, Ti, etc.
		Earthy	Mn OH, etc.
	C. one direction.	Ortho.	$(Mg\,Fe)_4\,B_2\,Ti\,O_9.$
			$Mn\,O_2$, etc.
	C. rhombohedral.	Hex.	UO_2, etc.
	F. uneven.	Ortho	$(Fe\,Mn).(Nb\,Ta)_2\,O_6.$
	F. pyramidal.	Tet.	$Mn\,O.\ Mn\,O_2.$
	F. uneven.	Hex.	$Al_2\,O_3$ with $Fe_3\,O_4.$

STREAK COLORED. INFUSIBLE.

NAME.	PAGE IN DANA.	HARDNESS.	GRAVITY.	LUSTRE.	COLOR.
3. STREAK GREEN.					
Zaratite	367	3 - 3.2	2.6- 2.7	vitreous.	green.
°Dioptase	424	5	3.2- 3.3	vitreous.	green.
Uraninite	521	5.5	6.4- 9.7	greasy, dull.	brown to black, var.
°Turquois	512	6	2.6- 2.8	waxy.	blue to green.
Periclase	331	6	3.6- 3.9	vitreous.	green, white.
°Gadolinite	436	6.5- 7	4 - 4.5	vitreous.	black, brown.
Hercynite	339	7.5- 8	3.9	dull, vitreous.	black.
4. STREAK RED.					
Greenockite	294	3 - 3.5	4.8- 5	adamantine.	yellow.
Xenotime	494	4 - 5	4.4- 4.5	resinous.	red to brown.
Turgite	350	5 - 6	3.5- 4.6	submetallic.	red to black.
Martite	336	6 - 7	4.8- 5.3	submetallic.	black.
Columbite	490	6	5.3- 7.3	submetallic.	grayish black.
5. STREAK BROWN.					
*Wad	352	½ - 6	3 - 4.2	dull.	brown to black.
Wurtzite	295	3.5- 4	4	pearly, adamantine.	brown to black.
Sphalerite	291	3.5- 4	3.9- 4.2	resinous.	brown, red, var.
Xenotime	494	4 - 5	4.4- 4.5	resinous.	yellow to red,
Pyrochlore	489	5 - 5.5	4.2- 4.3	vitreous, resinous.	brown. [var.
Hausmannite	342	5 - 5.5	4.7- 4.8	submetallic.	brown to black.
Psilomelane	352	5 - 6	3.7- 4.7	submetallic.	iron black.
Aeschynite	493	5 - 6	4.9- 5.1	resinous.	black.
Polycrase	493	5 - 6	4.9- 5.1	bronze.	black.
Microlite	489	5.5	5.5- 6.1	vitreous, resinous.	yellow to brown
Uraninite	521	5.5	6.4- 9.7	greasy, dull.	brown to black, var.
Fergusonite	490	5.5- 6	4.3- 5.8	submetallic.	brown to black.
Samarskite	492	5.5- 6	5.4- 5.7	vitreous, resinous.	black.
Martite	336	6	4.8- 5.3	submetallic.	black.
°Cassiterite	344	6 - 7	6.4- 7.1	adamantine, dull.	gray. brown, black, var.
°Rutile	345	6 - 6.5	4.1- 4.2	metallic, adamantine.	yellow to black, var.
Braunite	343	6 - 6-5	4.7- 4.8	submetallic.	brown, black,
Polymignite	493	6.5	4.7- 4.8	submetallic.	black. [gray
6. STREAK BLACK.					
Wad	352	½ - 6	3 - 4.2	dull,	brown to black.
Warwickite	519	3 - 4	3.2- 3.4	pearly, vitreous	black, brown.
Psilomelane	352	5 - 6	3.7- 4.7	submetallic.	iron black.
Uraninite	521	5.5	6.4- 9.7	greasy, dull.	brown to black, var.
Columbite	490	6	5.3- 7.3	submetallic.	gray to black.
Braunite	343	6 - 6.5	4.7- 4.8	submetallic.	brown, black, gray.
Emery	268	9	4	vitreous.	black.

*A variety containing nickel is called Asbolite.

°Often used as a gem stone.

REMARKS.	CLEAVAGE OR FRACTURE.	CRYSTAL SYSTEM.	COMPOSITION.
	F. uneven.	Iso.	$As_2 O_3$.
	F. uneven.	Iso.	$Sb_2 O_3$.
	C. pinacoidal.	Mono.	$As_2 O_3$.
	C. pinacoidal.	Ortho.	$Sb_2 O_3$.
	C. prismatic.	Mono.	$Na_2 CO_3$. $Ca CO_3$. $5 H_2O$.
	C. basal.	Mono.	$2 Pb CO_3 (Pb OH)_2 SO_4$.
	C. basal, prismatic.	Tet.	$Pb CO_3$. $Pb Cl_2$.
Cerussite and Witherite are used as pigments.	F. conchoidal.	Ortho.	$Pb CO_3$.
	F. uneven.	Ortho.	$Ba CO_3$.
			$Bi O. (Bi 2 OH) CO_3$.
Lapis Lazuli is used to some extent in the manufacture of ultramarine blue. It was the sapphire of the ancients. It is really not a mineral, but a mixture of hauyne and some colorless silicate. The so-called gold which it sometimes contains is pyrite.	C. basal.	Mono.	$Ca SO_4$. $Na_2 SO_4$.
	C. basal.	Ortho.	$Pb SO_4$.
	F. uneven.	Iso.	$(Na_2 Ca)_2 (Al Na S_3) Al_2 (SiO_4)_3$.
		Fib.	$Na Ca B_5 O_9$. $8 H_2O$.
	F. splintery.	Ortho.	$H (Mn Mg Zn) BO_3$.
	C. pinacoidal.	Mono.	$Ca_2 B_6 O_{11}$. $5 H_2O$.
	F. uneven.	Mono.	$Ca (B OH)$. SiO_4.
	C. pinacoidal.	Tri.	$H_2 (Ca Mn Mg Fe Zn)_4 Al_3 (SiO_4)_5$.
Cryolite, formerly the principal source of aluminium, is now used principally for the manufacture of C. P. soda and alum, and to some extent in the manufacture of glass. Its use as an ore of aluminium is much restricted. See note under Beauxite, p. 2.	F. conchoidal.	Iso.	$Mg_7 Cl_2 B_{16} O_{30}$.
	F. conchoidal.	Hex.	Al, Fe, Mg, B, Si, O_2.
	C. pinacoidal.	Mono.	$H Ca As O_4$. $2 H_2O$.
	F. uneven.	Ortho.	$Fe As O_4$. $2 H_2O$.
	C. pinacoidal.	Mono.	$3 Na F$. $Al F_3$.
	F. uneven.	Mono.	$Na Ca Al F_6$. H_2O.
	C. basal.	Tet.	$H_7 K Ca_4 (Si O_3)_8$. $4\frac{1}{2} H_2O$.
	F. uneven.	Tet.	$Pb Mo O_4$.
Vanadinite. See note under Descloizite, p. 8.	F. uneven.	Hex.	$3 Pb_3 (VO_4)_2$. $Pb Cl_2$.
	C. basal.	Tet.	$Pb Mo O_4$.
	F. uneven.	Hex.	$3 Pb_3 (As O_4)_2$. $Pb Cl_2$.
	F. uneven.	Hex.	$3 Pb_3 (PO_4)_2$. $Pb Cl_2$.
	C. basal.	Ortho.	$Li (Fe Mn) PO_4$.

WHITE. EASILY FUSIBLE.

NAME.	PAGE IN DANA.	HARDNESS.	GRAVITY.	LUSTRE.	COLOR.
1. VOLATILIZE, B. B.					
Arsenolite	330	1.5	3.7	silky.	white.
Senarmontite	330	2.5	5.2- 5.3	resinous.	gray.
Claudetite	330	2.5	3.8	pearly.	white.
Valentinite	330	2.5- 3	5.5	pearly.	white to red.
2. REACT FOR CO_2.					
Gay Lussite	366	2 - 3	1.9- 2	vitreous.	white.
Leadhillite	529	2.5	6.2- 6.4	resinous, adamantine, pearly.	white, yellow, green.
Phosgenite	364	2.7- 3	6 - 6.3	adamantine.	white, gray, yellow.
Cerussite	363	3 - 3.5	6.4- 6.5	submetallic, adamantine.	white, variable.
Witherite	362	3 - 3.7	4.2- 4.3	vitreous.	white, variable.
Bismutite	367	4 - 4.5	6.8- 6.9	vitreous.	white, variable.
3. REACT FOR H_2SO_4.					
Glauberite	523	2.5- 3	2.6- 2.8	vitreous.	yellow, variable.
Anglesite	527	2.7- 3	6.1- 6.4	adamantine.	white, variable.
°Lapis Lazuli	413	5.5- 6	2.3- 2.4	vitreous.	blue to green.
4. REACT FOR B_2O_3.					
Ulexite	520	1	1.6	silky.	white.
Sussexite	518	3	3.4	silky.	white.
Colemanite	519	4 - 4.5	2.4	vitreous.	white.
°Datolite	435	5 - 5.5	2.8- 3	vitreous.	white, variable.
°Axinite	441	6.5- 7	3.2- 3.3	vitreous.	brown, variable.
Boracite	518	7	2.9- 3	vitreous.	white.
°Tourmaline	447	7 - 7.5	2.9- 3.3	vitreous.	black, brown, var.
5. REACT FOR As_2O_3.					
Pharmacolite	510	2 - 2.5	2.6- 2.7	vitreous.	white to red.
Scorodite	509	3.5- 4	3.1- 3.3	vitreous.	green to brown.
6. REACT FOR HF.					
Cryolite	321	2.5	2.9- 3	vitreous.	white, variable.
Pachnolite	323	2.5- 4	2.9- 3	vitreous.	white.
Apophyllite	452	4.5- 5	2.3- 2.4	pearly.	white.
7. REACT FOR MoO_3.					
Wulfenite	541	2.7- 3	6 - 7	resinous, adamantine.	yellow, variable.
8. REACT FOR Pb.					
*Vanadinite	500	2.5- 3	6.6- 7.2	resinous.	yellow, red, brown.
Wulfenite	541	2.7- 3	6 - 7	resinous, adamantine.	yellow, variable.
Mimetite	500	3.5	7 - 7.2	resinous.	yellow, brown.
Pyromorphite	499	3.5- 4	5 - 7.1	resinous.	yellow, green, brown.
9. REACT FOR Li.					
Triphylite	496	4.5- 5	3.5- 3.6	subresinous.	green, blue, red, yellow, brown.

*Endlichite, a variety containing As.
°Sometimes used as a gem stone.

BRITTLE MINERALS,

INSOLUBLE IN WATER. STREAK

REMARKS.	CLEAVAGE OR FRACTURE.	CRYSTAL SYSTEM.	COMPOSITION.
The Zeolites have all been deposited from solution in cavities and cracks in rocks.	C. basal.	Mono.	$Li\ K\ [Al\ (OH\ F)_2]\ Al\ (SiO_3)_3$.
	C. pinacoidal.	Mono.	$H_4\ Ca\ Na_2)\ Al_2\ (SiO_3)_6 .\ 4\ H_2O$.
	C. pinacoidal.	Mono.	$H_4\ (Ca\ Na_2)\ Al_2\ (SiO_3)_6 .\ 3\ H_2O$.
	C. prismatic.	Hex.	$(Ca\ Na_2)\ Al_2\ (SiO_3)_4 .\ 6\ H_2O$.
	C. rhombohedral.	Hex.	$(Ca\ Na_2)\ Al_2\ (SiO_3)_4 .\ 6\ H_2O$.
	C. basal.	Tet.	$H_7\ K\ Ca_4\ (SiO_3)_8 .\ 4\frac{1}{2}\ H_2O$.
	C. pinacoidal.	Mono.	$H\ Na\ Ca_2\ (SiO_3)_3$.
	C. prismatic.	Hex.	$H_6\ (Na_2\ Ca)_4\ (Al\ Na\ CO_3)_2\ Al_6\ (SiO_4)_9$.
Lapis Lazuli. See note, p. 12.	C. prismatic.	Tet.	$Ca_4\ Al_6\ Si_6\ O_{25} .\ Na_4\ Al_3\ Si_9\ O_{24}\ Cl$.
	C. uneven.	Iso.	$Na\ Al\ (SiO_3)_2 .\ H_2O$.
	C. prismatic.	Mono.	$Ca\ Al\ (Al.\ 2\ OH)\ (SiO_3)_3 .\ 2\ H_2O$.
	C. prismatic.	Ortho.	$Na_2\ Al\ (Al\ O)\ (SiO_3)_3 .\ 2\ H_2O$.
	C. pinacoidal.	Ortho.	$Ca\ Na_2\ Al_2\ (SiO_4)_2 .\ ^5/_2\ H_2O$.
Sulphur is used in manufacturing gunpowder, matches, and sulphuric acid, and in bleaching.	F. uneven.	Mono.	$Ca\ (B\ OH)\ SiO_4$.
			$(Na_2\ Ca)_2\ (Al\ Na\ S_3)\ Al_2\ (SiO_4)_3$.
	F. uneven.	Ortho.	$H_2\ Ca_2\ Al_2\ (SiO_4)_3$.
	C. pinacoidal.	Tri.	$H_2 (CaMgFeMn\ Zn)_4 (BO)\ Al_3 (SiO_4)_5$
	C. prismatic.	Mono.	$Na\ Al\ Si_2O_6$.
	F. conchoidal.	Ortho.	S.

BRITTLE MINERLAS,

INSOLUBLE IN WATER. STREAK

REMARKS.	CLEAVAGE OR FRACTURE.	CRYSTAL SYSTEM.	COMPOSITION.
Barite is principally used as an adulterant for paints and other substances where weight is desirable.	C. 3 directions.	Mono.	$Ca\ SO_4 .\ 2\ H_2O$.
	C. basal.	Ortho.	$Ba\ SO_4$.
	C. 3 directions.	Ortho.	$Ca\ SO_4$.
Celestite is principally used in the manufacture of fireworks.	C. basal.	Ortho.	$Sr\ SO_4$.
Fluorite, Fluorspar, is principally used in metallurgy; and in the manufacture of hydrofluoric acid, and of glass. Most of the commercial supply is obtained in Hardin county, Illinois, and the adjoining portions of Illinois and Kentucky.	C. octahedral.	Iso.	$Ca\ F_2$.
	F. uneven.	Mono.	$Mg\ (Mg\ F)\ PO_4$.
	C. pinacoidal.	Mono.	$Ca\ (Al\ 2\ OH)_2\ (Si_2O_5)_2\ 2\ H_2O$.
	C. basal.	Ortho.	$Na\ (Be\ F)\ Ca\ (SiO_3)_2$.
	C. pinacoidal.	Mono.	$(Ca\ K_2\ Na_2)\ Al_2\ (SiO_3)_4 .\ 4\ H_2O$.
	C. pinacoidal.	Mono.	$(Ba\ K_2)\ Al_2\ (Si_5O_{14} .\ 5\ H_2O$.
	C. pinacoidal.	Mono.	$Ca\ SiO_3$.

White. Easily Fusible.

Name.	Page in Dana.	Hardness.	Gravity.	Lustre.	Color.
10. React for SiO_2.					
°Lepidolite	467	2 5- 4	2.8- 3	pearly.	rose red, white.
Stilbite	456	3.5- 4	2 - 2.2	pearly, vitreous.	white, var.
Heulandite	454	3.5- 4	2.1- 2.2	pearly, vitreous.	white, variable.
*Gmelinite	459	4.5	2 -2.17	vitreous.	yellow, red, [white.
Chabazite	458	4 - 5	2 - 2.2	vitreous.	white to red.
Apophyllite	452	4.5- 5	2.3- 2.4	pearly.	white.
°*Pectolite	395	5	2.6- 2.8	silky.	white.
°Cancrinite	411	5 - 6	2.4- 2.5	vitreous.	white, var.
°†Wernerite	425	5 - 6	2.6- 2.8	vitreous, pearly.	white, variable.
*Analcite	460	5 - 5.5	2 - 2.3	vitreous.	white.
*Scolecite	462	5 - 5.5	2.1- 2.4	vitreous.	white.
°*Natrolite	461	5 - 5.5	2.1- 2.2	vitreous, pearly.	white, variable.
°*Thomsonite	462	5 - 5.5	2.3- 2.4	vitreous, pearly.	white, brown, [green.
°*Datolite	435	5 - 5.5	2.8- 3	vitreous.	white, variable.
°*Lapis Lazuli	413	5 5- 6	2.3- 2.4	vitreous.	blue to green.
°Prehnite	442	6 - 6.5	2.8- 2.9	vitreous.	green, variable.
°*Axinite	441	6.5- 7	3.27- 3.3	vitreous.	brown, variable.
°Jadeite	393	6.5- 7	3.3- 3.4	pearly, sub- [vitreous.	green, white.
11. React for SO_2.					
Sulphur	274	1.5- 2	2	resinous.	yellow, brown.

°Sometimes used as gem stones. †Also called Scapolite. *Gelatinize with acids.

NON-METALLIC LUSTRE.

White. Fusibility Medium.

Name.	Page in Dana.	Hardness.	Gravity.	Lustre.	Color.
1. React for H_2SO_4.					
°Gypsum	531	1.5- 2	2.3	pearly, vitreous.	white, variable.
Barite	525	2.5- 3.5	4.3- 4.7	vitreous.	white, variable.
Anhydrite	528	3 - 3.5	2.8- 2.9	vitreous.	white to red.
°Celestite	526	3 - 3.5	3.9- 4	vitreous.	white to red.
2. React for HF.					
°Fluorite	320	4	3 - 3.2	vitreous.	white, variable.
‡Wagnerite	502	5 - 5.5	2.9- 3.1	vitreous.	yellow.
3. React for SiO_2.					
*Laumontite	457	3.5- 4	2.2- 2.3	vitreous.	white, variable.
Leucophanite	407	3.5- 4	2.9	vitreous.	green to yellow.
*Phillipsite	455	4 - 4.5	2.2	vitreous.	white to red.
Harmotome	456	4.5	2.4- 2.5	vitreous.	white, variable.
°*Wollastonite	394	4.5- 5	2.7- 2.9	vitreous.	white, variable.

*Gelatinize with Acids. ‡Reacts for P_2O_5 also.
°Sometimes used as gem stones.

REMARKS.	CLEAVAGE OR FRACTURE.	CRYSTAL SYSTEM.	COMPOSITION.
		Mono.	
Spodumene and lepidolite are now the main sources of lithium, which is used in the manufacture of fire works, and in medicine.	C. pinacoidal.	Mono.	$H\ Na\ Ca_2\ (SiO_3)_3$
	C. basal.	Tet.	Ca, Mg, Na, Fe, Al, Si,O.
	C. prismatic.	Mono.	$Ca\ Li\ SiO_5$
	C. basal.	Hex.	Na, Ca, Fe, Mn, Zr, Ce, Cl, (OH),Si
Rhodenite is used as an ornamental stone for inside decoration.	F. uneven.	Iso.	$Na\ Al\ (SiO_3)_2\ H_2O$
	C. prismatic.	Ortho.	$Na_2\ Al\ (AlO)\ (SiO_3)_3\ 2_2\ HO$
	C. prismatic.	Tet.	$Ca_4\ Al_6\ Si_6O_{25}\ Na_4\ Al_3\ Si_9O_{24}Cl$
	C. dodecahedral	Iso.	$Na_4\ (Al\ Cl)\ Al_2\ (SiO_4)_3$
	C. prismatic.	Hex.	$(Na_2\ K_2\ Ca)_4\ Al_8\ Si_9O_{34}$
	C. prismatic.	Tet.	$C_4\ Al_6\ Si_6O_{25}$
	C. prismatic.	Tri.	$Mn\ SiO_3$
	F. conchoidal.	Tet.	$(Ca\ Na)_3\ Al_2\ (SiO_4)_3$
Sunstone, Moonstone, Amazon Stone, Adular are varieties of feldspar which are used as precious stones.		Mono.	$(K\ Na)\ Al\ Si_3O_8$
		Tri.	$(Na\ K)\ Al\ Si_3O_8$
		Tri.	$Na\ Al\ Si_3O_8$
		Tri.	$3\ Na\ Al\ Si_3O_8.\ Ca\ Al_2\ Si_3O_8$
		Tri.	$Na\ Al\ Si_3O_9.\ Ca\ Al_2\ Si_3O_8$
The plagioclase feldspars, Albite to anorthite form a chemically continuous series, and grade into each other.		Tri.	$Na\ Al\ Si_3O_8.\ 3\ Ca\ Al_2\ Si_3O_8$
		Tri.	$Ca\ Al_2\ Si_3O_8$
	C. basal.	Mono.	$(Li\ Na)\ Al\ (Si_2O_5)_2$
	C. pinacoidal.	Ortho.	$Ca_2\ (Al\ OH)\ (Al_2)_2\ (SiO_4)_3$
	F. uneven.	Iso.	$(Be\ Mn\ Fe)_7\ Si_3O_{12}\ S$ -
	C. basal.	Mono.	$Ca_2\ (Al\ OH)\ (Al\ Fe)_2\ (SiO_4)_3$
The colors of garnets used as precious stones should be pure. The reds should have no purple. The yellows and greens no red or brown.	F. uneven.	Tet.	$Ca_6\ [Al(OH\ F)]\ (Al\ Fe)_2\ (SiO_4)_5$
			$Ca_3\ Al_2\ (SiO_4)_3$
			$(MgFeCa)_3Al_2(SiO_4)_3$
			$(Mn\ Fe\ Ca)\ (Al\ Fe)_2\ (SiO_4)_3$
			$Ca_3\ Cr_2\ (SiO_4)_3$
Almandite and andradite become magnetic on heating. Crushed garnet is much used as an abrasive.			$Fe_3\ Al_2\ (SiO_4)_3$
			$Ca_3\ Fe_2\ (SiO_4)_3$
	C. prismatic.	Mono.	$(Li\ Na)\ Al\ (SiO_3)_2$
	F. uneven.	Ortho.	$Ca\ B_2\ (SiO_4)_2$
	F. conchoidal.	Hex.	Al, Fe, Mg, Mn, Li, B, Si,O.

BRITTLE MINERALS,
INSOLUBLE IN WATER.

REMARKS.	CLEAVAGE OR FRACTURE.	CRYSTAL SYSTEM.	COMPOSITION.
The principal use of apatite is as a source of phosphorous. It was formerly much used as a fertilizer.	C. prismatic.	Ortho.	$Sr\ CO_3$
	C. rhombohedral.	Hex.	$Fe\ CO_3$
Deposits of natural phosphates are sometimes of organic origin. Sometimes replacement deposits. and sometimes indigenous to the crystalline rocks in which they occur.	C. prismatic.	Mono.	$Ca\ Ba\ (CO_3)_2$
	C. basal.	Hex.	$Ca_4\ (Ca\ F)\ (PO_4)_3$
	C. pinacoidal.	Ortho.	$(Fe\ Mn)\ (Al\ 2OH)\ PO_4.\ H_2O$
	C. pyramidal.	Tet.	$Ca\ WO_4$

NON-METALLIC LUSTRE.

STREAK WHITE. FUSIBILITY MEDIUM.

NAME.	PAGE IN DANA.	HARDNESS.	GRAVITY.	LUSTRE.	COLOR.
3. REACT FOR SiO_2.					
‖Amphibole	399	4 - 6.5	2.9- 3.5	pearly, resinous, vitreous.	white, green, variable.
Pyroxene	387				
°*Pectolite	395	5	2.6- 2.8	silky.	white.
*Melilite	426	5	2.9- 3.1	vitreous.	yellow to brown, var.
°Titanite	485	5 - 5.5	3.4- 3.5	adamantine, resinous.	gray, black, var.
*Eudialyte	407	5.5	2.9- 3	vitreous.	red.
*Analcite	460	5 - 5.5	2 - 2.3	vitreous.	white.
°*Natrolite	461	5 - 5.5	2.1- 2.2	vitreous, pearly.	white, var.
°‡Wernerite	425	5 - 6	2.6- 2.8	vitreous, pearly.	white, var.
°*Sodalite	412	5.5- 6	2.1- 2.4	vitreous.	green, variable.
°*Nephelite	409	5.5- 6	2.5- 2.6	vitreous, greasy.	white, variable.
†Meionite	425	5.5- 6	2.6- 2.7	vitreous.	white.
°§Rhodonite	395	5.5- 6.5	3.4- 3.7	vitreous.	red.
*Sarcolite	426	6	2.5- 2.9	vitreous.	red.
°Feldspar	369	6	2.5- 2.8	variable.	variable.
Sanidine			2.6		
Anorthoclase			2.6		
Albite			2.6		
Oligoclase			2.7		
Andesite			2.7		
Labradorite			2.7		
Anorthite			2.8		
Petalite	369	6 - 6.5	2.3- 2.4	vitreous.	white.
°†Zoisite	437	6 - 6.5	3.1- 3.4	pearly, vitreous.	white, variable.
*Helvite	414	6 - 6.5	3.1- 3.3	vitreous.	yellow to black, variable.
°†Epidote	438	6 - 7	3.2- 3.5	vitreous.	green to black, var.
°†Vesuvianite	427	6.5-	3.3- 3.4	vitreous.	brown to green.
°†Garnet	415	6.5- 7.5	3.1- 4.3	vitreous, resinous.	variable.
Grossularite		6.5- 7.5	3.5- 3.6		white, green, red.
Pyrope		6.5- 7.5	3.6- 3.7		pure red.
Spessartite		7 - 7.5	4.2		brown, red.
Ouvarovite		7.5	3.4- 3.5		green.
Almandite		7 - 7.5	4 - 4.1		red, brownish.
Andradite		7	3.7- 3.8		wine, green, brown.
°Spodumene	393	6.5- 7	3.1- 3.2	pearly.	white, variable.
°Danburite	431	7 - 7.2	2.9- 3	vitreous.	yellow to white.
°Tourmaline	447	7 - 7.5	2.9- 3.3	vitreous.	black, brown, var.

NON-METALLIC LUSTRE.

STREAK WHITE. FUSIBILITY DIFFICULT.

NAME.	PAGE IN DANA.	HARDNESS.	GRAVITY.	LUSTRE.	COLOR.
1. REACT FOR CO_2.					
Strontianite	362	3.5- 4	3.6- 3.7	vitreous.	white, variable.
Siderite	359	3.5- 4.5	3.7- 3.9	pearly, vitreous.	brown, variable.
Barytocalcite	364	4	3.6	vitreous.	white, variable.
2. REACT FOR P_2O_5.					
°Apatite	497	4.5- 5	2.9- 3.2	vitreous.	green, variable.
Childrenite	513	4.5- 5	3.1- 3.2	vitreous.	white, variable.
3. REACT FOR WO.					
Scheelite	540	4.5- 5	5.9- 6.1	vitreous.	white, variable.

‖For varieties see p. 8.
°Sometimes used as a gem stone.
*Gelatinize with Acids.
‡Also called Scapolite.
†Gelatinize after Fusion.
§Fowlerite, a variety containing Zn.

BRITTLE MINERALS,

INSOLUBLE IN WATER.

REMARKS.	CLEAVAGE OR FRACTURE.	CRYSTAL SYSTEM.	COMPOSITION.
Calamine is usually deposited from solution in water.	C. basal.	Foliated	$H_2 Mg_3 (SiO_3)_4$
		Earthy.	$H_4 Mg_2 Si_3O_{10}$
			$H_6 K_2 Al_2 Si_{15}O_{20}$
			$H_4(Mg Fe)_3 Si_2O_9$
The genuine emerald is a form of Beryl. See under corundum and quartz.	C. basal.	Mono.	$H_2 Ca Al_4 Si_2O_{12}$
		Mono.	
	C. prismatic.	Ortho.	$(Zn OH)_2 SiO_3$
	C. pinacoidal.	Ortho.	$Ca Mg SiO_4$
	C. prismatic.	Ortho.	$(Mg Fe) SiO_3$
	C. pinacoidal.	Mono.	Ca, Na. Zr, Nb, SiO
	C. basal.	Hex.	$Zn_2 SiO_4$
	C. prismatic.	Ortho.	$(Mg Fe) SiO_3$
	C. dodecahedral.	Iso.	$(Ca Na_2)_2 (Al Na SO_4) Al_2 (SiO_4)_3$
	C. prismatic.	Hex.	$(Na_2 K_2 Ca)_4 Al_8 Si_9O_{34}$
	C. basal.	Mono.	$H_2 Fe Al_2 SiO_7$
	C. 2 directions.		
See remark p. 15.		Mono.	$K Al Si_3 O_8. Ba Al_2 Si_2 O_8$
		Mono.	$K Al Si_3O_8$
		Tri.	$K Al Si_3O_8$
	C. basal.	Mono.	$(Li Na) Al (Si_2O_5)_2$
	F. conchoidal.	Iso.	$H_2 Cs_4 Al_4 (SiO_3)_9$
Orthoclase or "spar" is largely used in the manufacture of the finer grades of pottery.	F. conchoidal.	Hex.	Na, Li, Al, H, F, B, Si, O_2
	C. pinacoidal.	Ortho.	$H_2(Mg Fe)_4 Al_8 Si_{10}O_{37}$
	C. pinacoidal.	Mono.	$Be (Al OH) SiO_4$
	C. prismatic.	Hex.	$Be_2 SiO_4$
	F. conchoidal.	Hex.	$Be_3 Al_2 (SiO_3)_6 \frac{1}{2} H_2O$

STREAK WHITE. FUSIBILITY DIFFICULT.

NAME.	PAGE IN DANA.	HARDNESS.	GRAVITY.	LUSTRE.	COLOR.
1. REACT FOR SiO_2.					
Talc	479	1 - 1.5	2.7- 2.8	pearly.	green,white,var.
Sepiolite	480	2 - 2.5	1 - 1.5	dull.	white,variable.
Pinite	466	2.5- 3.5	2.6- 2.9	dull.	variable.
°Serpentine	476	2.5- 5 5	2.2- 2.6	resinous, pearly.	green, variable.
Margarite	470	3.5- 4.5	2.9- 3	pearly, vitreous.	white, var.
{ †Amphibole }	399	4 - 6.5	2.9- 3.5	pearly, vitreous,	green, variable.
{ Pyroxene }	387			[resinous.	
*Calamine	446	4.5- 5	3.4- 3.5	vitreous.	white, variable.
*Monticellite	422	5 - 5.5	3 - 3.2	vitreous.	colorless to gray.
°Enstatite	384	5.5	3.1- 3.3	pearly, vitreous.	white, gray, var.
Wöhlerite	395	5.5	3.4	vitreous.	variable.
*°Willemite	422	5.5	3.8- 4.3	vitreous, resinous.	variable.
Anthophyllite	398	5.5- 6	3.1- 3.2	pearly, vitreous.	brown to green.
*°Hauynite	412	5.5- 6	2.4- 2.5	vitreous.	blue, green, var.
*°Nephelite	409	5.5- 6	2.5- 2.6	vitreous, greasy.	white, var.
Chloritoid	471	5.2- 6.5	3.5- 3.6	pearly.	green, var.
Feldspar, Gr	369	6	2.5- 2.8	vitreous, resin-	variable.
Hyalophane			2.8	[ous, pearly.	
Orthoclase			2.6		
Microcline			2.6		
Petalite	369	6 - 6.5	2.3- 2.4	vitreous, pearly.	white.
Pollucite	382	6.5	2.9	vitreous.	colorless.
†°Garnet	415	6.5- 7.5	3.1- 4.3	vitreous, resinous.	variable.
°Tourmaline	447	7 - 7.5	2.9- 3.3	vitreous.	black, brown,
°Iolite	407	7 - 7.5	2.5- 2.6	vitreous.	blue. [var.
°Euclase	436	7.5	3 - 3.1	vitreous.	green and blue.
°Phenacite	423	7.5- 8	2.9- 3	vitreous.	colorless, [variable.
°Beryl	405	7.5- 8	2.6- 2.7	vitreous.	white, blue, var.

*Gelatinize with Acids. †Gelatinize after Fusion.
°Sometimes used as a gem stone.
+For varieties see p. 8.

REMARKS.	CLEAVAGE OR FRACTURE.	CRYSTAL SYSTEM.	COMPOSITION.
The variety of calcite known as Iceland Spar is largely used for optical purposes.		Earthy.	$2\ ZnO_3.\ 3\ Zn\ (OH)_2$
	C. basal.	Ortho.	$La_2\ (CO_3)_3.\ 9\ H_2O$
	C. rhombohedral.	Hex.	$Ca\ CO_3$
		Mono.	$Mg_2\ (Mg\ OH)_2\ (CO_3)_3.\ 3\ H_2O$
Rhodochrosite is polished and used as an ornamental stone.	C. pinacoidal.	Ortho.	$Ca\ CO_3$
	C. rhombohedral.	Hex.	$Ca\ Mg\ (CO_3)_2$
	C. rhombohedral.	Hex.	$Ca\ (Mg\ Fe\ Mn)\ (CO_3)_2$
Magnesite is largely used as a refractory material, in bleaching, in the manufacture of fire-proofing materials, and medicines.	C. rhombohedral.	Hex.	$Mg\ CO_3$
	C. rhombohedral.	Hex.	$Mn\ CO_3$
	C. rhombohedral.	Hex.	$Zn\ CO_3$
	F. uneven.	Mono.	$Al_2\ (OH)_4\ SO_4.\ 7\ H_2O$
	C. pinacoidal.	Ortho.	$(Al\ OH)_3(PO_4)_2.5\ H_2O$
	C. prismatic.	Mono.	$(Mg\ Fe)\ (Al\ OH)_2\ (PO_4)_2$
			$Al_2\ (OH)_3\ PO_4.\ H_2O$
	F. conchoidal.	Hex.	$K\ (Al\ O)_3(SO_4)_2.\ 3\ H_2O$
			$(Y\ Er\ Ce)\ F_3.\ 5\ Ca\ F_2.\ H_2O$
	C. basal.	Ortho.	$Mg_5\ [Mg\ (F\ OH)]_2\ (Si\ O_4)_3$
	C. cubic.	Iso.	$Ca\ Ti\ O_3$
	C. basal.	Tet.	$Ti\ O_2$
	F. uneven.	Ortho.	$Ti\ O_2$
		Ortho.	$Sb_2\ O_4$
	F. conchoidal.	Ortho.	$(Fe\ Ca)\ (Y\ Er\ Ce)_2\ (Ta\ Nb)_4\ O_{15}$
	C. basal.	Mono.	$H_4\ Al_2\ Si_2O_9$
	C. basal.	Mono.	$Al\ (OH)_2$
			$Al_2\ SiO_5.\ 5\ H_2O$

STREAK WHITE. INFUSIBLE.

NAME.	PAGE IN DANA.	HARDNESS.	GRAVITY.	LUSTRE.	COLOR.
1. REACT FOR CO_2.					
Hydrozincite	366	2 - 2.5	3.5- 3.8	dull.	white, variable.
Lanthanite	366	2.5- 3	2.6	pearly.	white, variable.
Calcite	354	2.5- 3.5	2.5- 2.8	vitreous.	white, variable.
Hydromagnesite	367	3.5	2.1- 2.2	vitreous.	white.
°Aragonite	361	3.5- 4	2.9	vitreous.	white.
Dolomite	357	3.5- 4	2.8- 2.9	vitreous.	white, variable.
Ankerite	358	3.5- 4	2.9- 3.1	vitreous, pearly.	white, variable.
Magnesite	358	3.5- 4.5	2.8- 3.2	vitreous.	white to brown.
°Rhodochrosite	359	3.5- 4.5	3.4- 3.7	vitreous.	red to pink.
Smithsonite	360	5	4 - 4.4	vitreous.	white, variable.
2. REACT FOR H_2SO_4.					
Aluminite	537	1 - 2	1.66	dull.	white.
Alunite	396	3.5- 4	2.5- 2.7	vitreous.	white, variable.
3. REACT FOR P_2O_5.					
Wavellite	512	3.2- 4	2.3	vitreous.	white, variable.
°Lazulite	506	5 - 6	3 - 3.1	vitreous.	blue.
°Turquois	512	6	2.6- 2.8	waxy.	blue to green.
4. REACT FOR HF.					
Yttrocerite	323	4 - 5	3.4- 3.5	vitreous.	white to blue, var.
Humite	443	6 - 6.5	3.1- 3.2	vitreous, resinous.	white, yellow, red.
5. REACT FOR TiO_2.					
Perovskite	487	5.5	4	adamantine.	yellow to black.
°Octahedrite	346	5.5- 6	3.8- 4.1	metallic, adamantine.	brown, black, blue.
Brookite	347	5.5- 6	3.8- 4.2	metallic, adamantine.	brown to black.
6. REACT FOR Sb_2O_3.					
Cervantite	330	4.5	4	pearly.	yellow.
7. REACT FOR YO.					
Yttrotantalite	492	5 - 5.5	5.4- 5.9	sub-metallic, greasy.	yellow, black, brown.
8. REACT FOR Al_2O_3.					
Kaolinite	481	1 - 2.5	2.4- 2.6	dull.	variable.
Gibbsite	351	2.5- 3.5	2.3- 2.4	dull, pearly.	white to green.
*Allophane	483	3	1.8- 1.9	vitreous, resinous.	blue, green, variable.

*Gelatinize with HCl.
°Often used as gem stones.

REMARKS.	CLEAVAGE OR FRACTURE.	CRYSTAL SYSTEM.	COMPOSITION.
			$Al_2 O (OH)_4$.
	C. pinacoidal.	Tri.	$Al_2 SiO_5$.
	F. uneven.	Iso.	$K Al (SiO_3)_2$.
	C. pinacoidal.	Ortho.	$Al_2 SiO_5$.
	C. pinacoidal.	Ortho.	$AlO (OH)$
	F. conchoidal.	Hex.	Na,Al,Li,H,F,B,Si,O_2
	C. prismatic.	Ortho.	$Al_2 SiO_5$.
	F. conchoidal.	Iso.	$Mg Al_2 O_4$.
	C. basal.	Ortho.	$(Al F)_2 SiO_4$.
	C. prismatic.	Ortho.	$Be Al_2 O_4$.
Corundum is mostly used as an abrasive. When mixed with Magnetite it is called emery. It is an ore of aluminium. The purer varieties of various colors give us the Sapphire Ruby, Oriental Topaz, Oriental Emerald, and Oriental Amethyst. The colorless crystals resemble the diamond closely when properly cut.		Hex.	$Al_2 O_3$.
	C. basal.	Mono.	$H_4 Al_2 Si_2 O_9$.
			$Cu SiO_3 2H_2O$.
	C. basal.	Mono.	$Al_2 SiO_5 . {}_5H_2O$.
			An impure earthy Genthite.
			$H_4Ni_2Mg_2(SiO_4)_3 4H_2O$
	C. pinacoidal.	Tri.	$Al_2 SiO_5$.
	C. prismatic.	Ortho.	$(Mg Fe) SiO_3$.
	F. uneven.	Iso.	$K Al (SiO_3)_2$.
Chrysolite, Olivine or Peridot is a constituent of basic rocks and meteorites. Its purer varieties are much sold as topaz and emeralds. It decomposes into serpentine.	F. conchoidal.		$SiO_2 . H_2O$.
	C. basal.	Ortho.	$Mg_5 [Mg(F OH)]_2 (SiO_4)_3$.
	C. pinacoidal.	Ortho.	Al_2SiO_5.
	C. pinacoidal.	Ortho.	$(Mg Fe) SiO_4$.
	F. conchoidal.	Hex.	SiO_2.
All the transparent or attractively colored varieties of quartz are used as gem stones. Many of these are commonly sold as gems of greater value, and the best grades cannot be told from genuine stones by most people, unless they apply physical tests. Quartz "Flint" is largely used in the manufacture of pottery. It is also used as an abrasive, in the manufacture of glass, for optical purposes, and as an adulterant.			

NON-METALLIC LUSTRE.

NAME.	PAGE IN DANA.	HARDNESS.	GRAVITY.	LUSTRE.	COLOR.
Beauxite	350	3	2.5	earthy.	
Cyanite	434	5 - 7	3.4- 3.7	vitreous, pearly.	blue, variable.
Leucite	381	5.5- 6	2.4- 2.5	vitreous.	white to gray.
Sillimanite	433	6 - 7	3.2- 3.3	vitreous.	brown. green, [var.
°Diaspore	348	6.5- 7	3.3- 3.5	pearly, vitreous.	white, variable.
°Tourmaline	447	7 - 7.5	2.9- 3.1	vitreous.	black, variable.
°Andalusite	432	7.5	3.1- 3.3	vitreous.	white, variable.
°Spinel	338	8	3.5- 4.1	vitreous, dull.	red, black, [variable.
°Topaz	431	8	3.4- 3.6	vitreous.	yellow, variable.
°Chrysoberyl	342	8.5	3.5- 3.8	vitreous.	green.
°Corundum	333	9	3.9- 4.2	vitreous.	blue, gray. [variable.
9. REACT FOR SiO_2.					
Kaolinite	481	1 - 2.5	2.4- 2.6	dull.	variable.
°Chrysocolla	483	2 - 4	2 - 2.2	vitreous.	green to blue.
*Allophane	483	3	1.8- 1.9	vitreous, resinous.	blue, green, [variable.
Garnierite	479		2.4	earthy.	
Genthite	479	3 - 4	2.4	resinous.	green, yellow.
°Cyanite	434	5 - 7	3.4- 3.7	vitreous, pearly.	blue, variable.
°Enstatite	384	5.5	3.1- 3.3	pearly, vitreous.	white, gray, var.
Leucite	381	5.5- 6	2.4- 2.5	vitreous.	white to gray.
°Opal	329	5.5- 6.5	1.9- 2.3	vitreous, pearly.	white, variable.
Humite	443	6 - 6.5	3.1- 3.2	vitreous, resinous.	white, variable.
Fibrolite	433	6 - 7	3.2- 3.3	vitreous.	brown, green, [var.
°*Chrysolite	420	6 - 7	3.3- 3.5	vitreous.	green.
°Quartz	324	7	2.5- 2.8	vitreous.	white, variable.

Phenocrystatlline varieties:

- Rock Crystal, transparent colorless.
- Amethyst, purple to violet.
- Rose Quartz, pink to red.
- False Topaz, yellow.
- Smoky Quartz, Cairngorm, brown to black.
- Milky Quartz, white, nearly opaque.

Cryptocrystalline varieties:

- Chalcedony, varieties with waxy lustre.
  - Carnelian, red chalcedony.
  - Chrysophrase, apple green chalcedony.
  - Prase, dull green chalcedony.
  - Plasma or Heliotrope, bright emerald green.
- Agate, banded.
  - Onyx, bands black and white, straight.
  - Sardonyx, some bands red, straight.
  - Moss Agate, filled with dendritic forms.
- Jasper, dull, opaque, colors various, rather bright.
- Silicious Sinter, Silica deposited by springs.
- Flint, dull, opaque, colors dull, usually gray, brown, black.
  - Hornstone or Chert, fracture splintery.

---

*Gelatinize with HCl.
°Often used as gem stones.

BRITTLE MINERALS,

INFUSIBLE IN WATER.

REMARKS.	CLEAVAGE OR FRACTURE.	CRYSTAL SYSTEM.	COMPOSITION.
	F. conchoidal.	Hex.	SiO_2.
	F. conchoidal.	Hex.	Na,Li,Al,H,F,B,Si,O_2
	C. pinacoidal.	Ortho.	$(Al\,O)_4\,(Al\,OH)\,Fe\,(Si\,O_4)_2$.
	C. prismatic.	Ortho.	$Al_2\,SiO_5$.
	C. prismatic.	Tet.	$Zr\,SiO_4$.
	C. prismatic.	Hex.	$Be_2\,SiO_4$.
	C. basal.	Ortho.	$(Al\,F)_2\,SiO_4$.
	C. tetrahedral.	Iso.	C

METALLIC LUSTRE.

STREAK WHITE. INFUSIBLE.

NAME.	PAGE IN DANA.	HARDNESS.	GRAVITY.	LUSTRE.	COLOR.
Tridymite	328	7	2.2- 2.3	vitreous.	white.
°Tourmaline	447	7 - 7.5	2.9- 3.3	vitreous.	black, variable.
°Staurolite	450	7 - 7.5	3.5- 3.8	subvitreous.	brown to black.
°Andalusite	432	7.5	3 - 3.3	vitreous.	white, variable.
°Zircon	429	7.5	4.2- 4.8	adamantine.	brown, variable.
°Phenacite	423	7.5- 8	2.9- 3	vitreous.	white, variable.
°Topaz	431	8	3.4- 3.6	vitreous.	yellow, variable.
10. BURN WITHOUT FUSION.					
°Diamond	271	10	3.5	adamantine.	white to black.

°Sometimes used as a gem stone.

INDEX TO MINERALS